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JOURNAL OF THE AERONAUTICAL SCIENCES

Volume 4 DECEMBER, 1936 Number 2

On the Results of Aerodynamic Research and Their Application to Aircraft Construction

CLARK B. MILLIKAN, *California Institute of Technology*

Presented at the Annual Meeting of the Lilienthal-Gesellschaft für Luftfahrtforschung, Germany October 13, 1936

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IN the first part of the paper, the author proposes to discuss briefly some of the problems which appear to him to have most seriously occupied the thoughts of American designers and research workers during the past year. Such a discussion will of necessity be extremely cursory and the choice of subject matter inevitably colored by the interests and contacts of the author. It is hoped, therefore, that the author may be forgiven for the omission of many subjects which must appear to numbers of aeronautical workers to be of equal or greater importance than those which he has selected. In the second portion of the paper, he discusses the question of the cooperation of small, independent research organizations with practical designers in attacking the latter's problems, and concludes with the presentation of some statistical data which have been collected during the course of several years of such cooperative effort. This second portion of the paper is based practically entirely upon personal experience with the specific aeronautical laboratory with which the author has the honor of being connected, and represents, therefore, a somewhat restricted point of view.

Except insofar as special military requirements force modifications, almost all relatively large modern American airplanes have very similar "three-views" (comparing only airplanes in a given class as to number of engines). Furthermore, the "three-views" of the latest airplanes now on the drafting table are superficially very much like those of the airplanes which were already in regular service a year ago. This practical elimination of questions connected with the effect of general external shape on the aerodynamicist's basic problems, "performance" and "flying qualities", has shifted the emphasis of his considerations to other phases of these problems.

Considering first "performance," the question of surface roughness has received much attention. The decision as to the value of extreme precautions to reduce surface roughness with modern metal construction is largely an economic one. In order to make an intelligent comparison between the cost of butt-joints, flush rivets, flush windows, etc., and the savings following their use, a large amount of aerodynamic knowledge of their effects is essential. In spite of the excellent researches in this field, especially in Germany, much more work remains to be done and is indeed now planned or in progress. The status of the question at present as regards actual designs in the United States is about as follows:

* Considerable portions of the paper, as originally presented in German, have been omitted. The original paper was published, in German, in *Luftwissen*, Bd. 3. Nr. 10, October 1936, pages 277–287.

Most high performance airplanes now being built have flush riveting and butt joints near the wing leading edge, while several planes under design have the entire surface so finished and are to be provided with flush windows and doors. Whether or not such refinements can be justified in all cases remains to be seen.

With overall shape fairly standardized, surface roughness reduced to a minimum, and the amount of power limited for economic reasons with existing engines, the only method of improving performance (at least insofar as the aerodynamicist is concerned) is to improve the aerodynamic conditions under which the airplane operates. This can be accomplished in two ways: by careful analysis of optimum cruising or other operating conditions, and by flying at very high altitudes. The first question was discussed before your society by E. T. Allen last year, and will be briefly mentioned again below. The second has been actively investigated during the past year although very few actual stratosphere airplanes have as yet been designed and flown.

The crucial problems of the stratosphere airplane appear to be connected with the fields of structures, engines, and accessories, involving the design of pressure cabins, very highly supercharged engines, and regulating equipment for extremely precise and reliable pressure control. As such, they lie outside the scope of the present paper. However, the interest in stratosphere planes has furnished aerodynamicists with at least one problem which has been vigorously pursued during the past year. This is the analysis of the effect of very high altitude flying on performance. An estimate of this effect must, of course, be made in order that it may be possible for operators and designers to decides whether the advantages outweigh the additional expense and complication involved in building stratosphere airplanes. Furthermore, in order that the types of operation may be determined for which stratosphere flying may be expected to be economical and useful, it has been necessary that these performance estimates be both elaborate and accurate. The methods of calculation must also be flexible in view of the uncertainty as to the exact characteristics of engines for stratosphere operations. In view of these needs, there has been a renewal of activity in the field of performance calculation and analysis. This has been accentuated by the development of new types of propellers (e. g. constant r.p.m.), by the necessity of choosing propellers with reference to take-off characteristics for planes with large speed range, and by the desire for accurate determination of "throttled" performance in order that optimum cruising conditions may be known. The last question has become even more important during the last year than when Mr. Allen discussed it before your society, because of the keen competition between commercial transport companies, and also in view of the development of long range transcontinental and transoceanic scheduled flights.

In the past few years, Oswald's methods of performance calculation[1] have been fairly widely employed in the United States. These methods are based essentially on a mathematical analysis of the problem (somewhat similar to those given in Germany by Schrenk and Helmbold), which replaces the more tedious graphical procedure. Based on this analysis, Oswald prepared a set of charts enabling the major elements in a performance estimate to be rapidly obtained. Unfortunately, in the construction of these charts, it was necessary to introduce empirical engine and propeller data. Oswald's original charts were based on the assumptions of full-throttle operation of unsupercharged engines and of fixed pitch propellers of a representative standard family, chosen so as to give maximum efficiency at maximum level speed. He subsequently developed methods of using the charts for engines with gear-driven superchargers. However, it is clear that practically none of the new performance problems mentioned above can be treated directly, even by the amplified Oswald Method. The extension to constant r. p. m. propellers (still, however, chosen to give maximum efficiency at maximum speed) is relatively simple, and charts covering this case have recently been published.[2] Even these are not applicable to most of the new problems, and several attempts at generalization have recently been made.

One, the work of W. C. Rockefeller, which has already been considerably used on the Pacific Coast and is now being published, recasts the Oswald analysis so that analytical expressions and final charts result which are completely independent of propulsive unit characteristics. The material in the charts may also be placed on the scales of a slide-rule which then embodies all of the results of the analysis. The charts or slide-rule are then used in conjunction with engine data and propeller curves for any arbitrary propulsive unit. Fig. 1 shows the slide-rule diagrammatically in the form in which it is now in the process of commercial manufacture. This method has been applied with considerable success to all of the performance problems mentioned above. As an example, Fig. 2 shows the ratio of the speed at any altitude to the speed at sea-level for airplanes with constant thrust-horsepower. The parameter Λ plotted

[1] W. Bailey Oswald, *General Formulas and Charts for the Calculation of Airplane Performance*, N.A.C.A. Tech. Rep. 408; also *Methods of Performance Calculation for Airplanes with Supercharged Engines Developed by W. Bailey Oswald*, A.C.I.C.679.

[2] Roland J. White and Victor J. Martin, *Charts for Calculating the Performance of Airplanes Having Constant Speed Propellers*, N.A.C.A. Tech. Note 579.

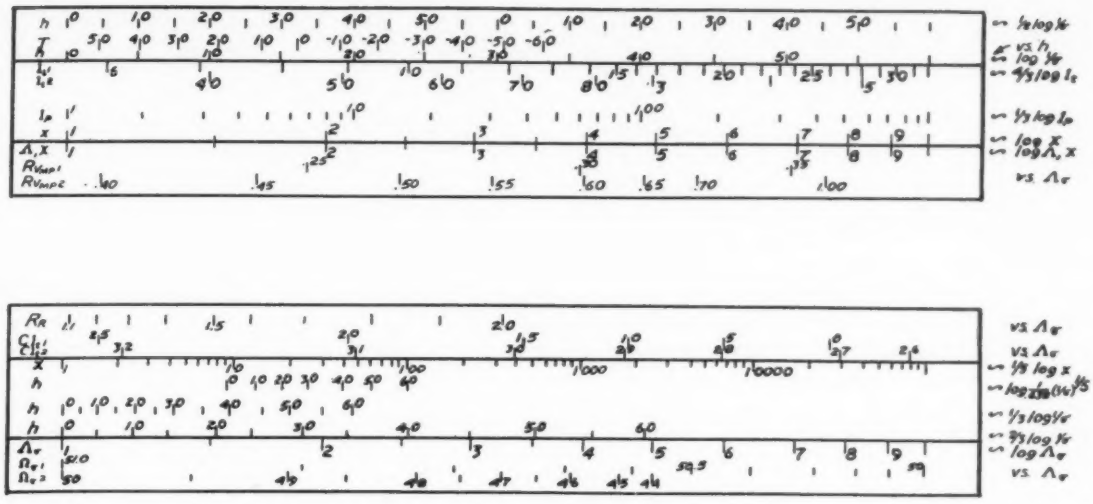


FIG. 1. Slide-rule for performance calculation (English units).

as abscissa, has been called the "fundamental performance parameter" and contains only the basic design quantities: weight, span, equivalent parasite area, and thrust-horsepower. In general, a low value of Λ corresponds to high performance and vice versa. The chart shows very strikingly the great gain in speed which may be obtained by extreme supercharging of high performance (low Λ) airplanes as compared with that possible for low performance (large Λ) ones. Corresponding to the two curves for speed ratio at absolute ceiling and maximum possible speed ratio, are the two very simple and rather interesting analytical expressions given on the figure for absolute ceiling and maximum possible velocity at any altitude. Although at moderate heights the maximum speed at a given altitude is not much affected by changes in weight, it is seen that the weight does enter very importantly into the maximum possible speed for an airplane with constant thrust-horsepower.

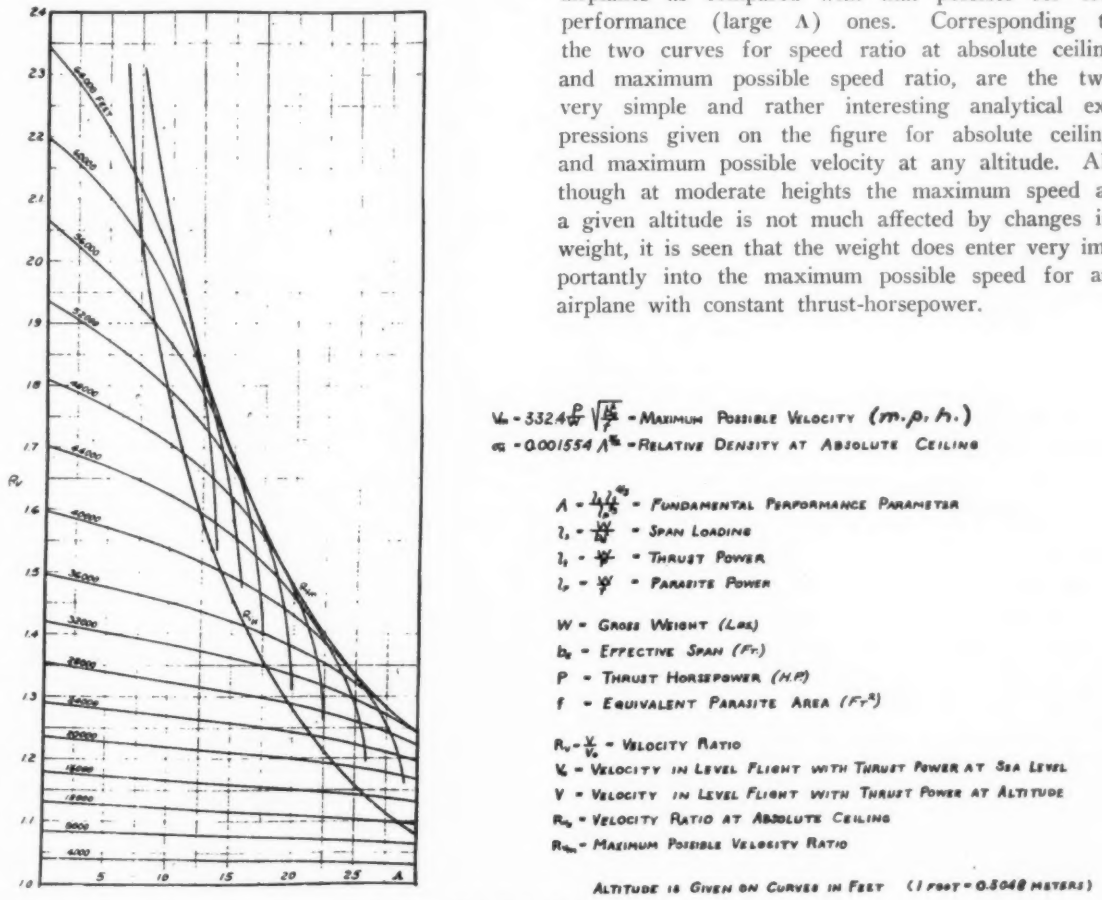

$V_m = 332.4 \frac{P}{W}\sqrt{\frac{b_e}{f}}$ = MAXIMUM POSSIBLE VELOCITY (m.p.h.)
$\sigma_c = 0.001554\,\Lambda^{\frac{10}{13}}$ = RELATIVE DENSITY AT ABSOLUTE CEILING
$\Lambda = \frac{\lambda_1 \lambda_2^{4/3}}{\lambda_p}$ = FUNDAMENTAL PERFORMANCE PARAMETER
$\lambda_2 = \frac{W}{b_e^2}$ = SPAN LOADING
$\lambda_1 = \frac{W}{P}$ = THRUST POWER
$\lambda_p = \frac{W}{f}$ = PARASITE POWER
W = GROSS WEIGHT (LBS.)
b_e = EFFECTIVE SPAN (FT.)
P = THRUST HORSEPOWER (H.P.)
f = EQUIVALENT PARASITE AREA (FT^2)
$R_v = \frac{V}{V_0}$ = VELOCITY RATIO
V_0 = VELOCITY IN LEVEL FLIGHT WITH THRUST POWER AT SEA LEVEL
V = VELOCITY IN LEVEL FLIGHT WITH THRUST POWER AT ALTITUDE
R_{v_c} = VELOCITY RATIO AT ABSOLUTE CEILING
R_{v_m} = MAXIMUM POSSIBLE VELOCITY RATIO
ALTITUDE IS GIVEN ON CURVES IN FEET (1 FOOT = 0.3048 METERS)

FIG. 2. Velocity-ratio chart.

Using methods like the above, and considering economic as well as aerodynamic factors, Rockefeller and others have made analyses of the advantages of commercial stratosphere flying. The chief conclusion from these analyses is that stratosphere flight appears economically feasible for distances between landings of the order of 1600 to 2400 kilometers. Several airplanes in the United States which have been equipped for sub-stratosphere operation are being flown experimentally, and a number of true stratosphere passenger planes are under design and construction. It therefore appears that the next few years should witness several attempts to verify the correctness of the theoretical considerations through actual flying operations.

Before leaving the subject of performance, it should be emphasized that methods of rapidly and accurately estimating performance have been considered, assuming the aerodynamic characteristics of the airplane as given. The problem of determining these characteristics is an entirely different one, some elements of which will be discussed in the second portion of the paper.

Attention can be given for a few moments to the subject of flying qualities, restricting this attention to the elements of stability and controllability. A few years ago, the pressure of operators on designers was largely for higher and higher performance. In the last year or so, performance, especially of commercial planes, has become more or less stabilized, the result being a much increased interest in stability and controllability problems. This has been greatly accentuated by the rapid increase in the size of projected airplanes, as will be discussed in more detail later in connection with hinge moments and control forces.

The classical problem of flying properties was that of "static longitudinal stability". One element in this very old problem has recently been the subject of much speculation and some active investigation, namely the effect of propeller slipstream on lift and pitching moment. The most satisfactory method of investigating this problem in the wind tunnel involves the use of motors mounted in airplane models and driving scale models of propellers at advance ratios covering the same range as those used in free flight. In such tests it is desirable that the propeller tip speed remain at approximately its full scale value, which implies that the revolutions per minute should be roughly proportional to the inverse of the model scale. Experiments of this type were made many years ago at Goettingen but the small sizes of the models then used and the consequent very high r. p. m. resulted in technical difficulties which greatly restricted the amount of experimental work carried out with the Goettingen type of apparatus. A few years ago at the California Institute of Technology, design and

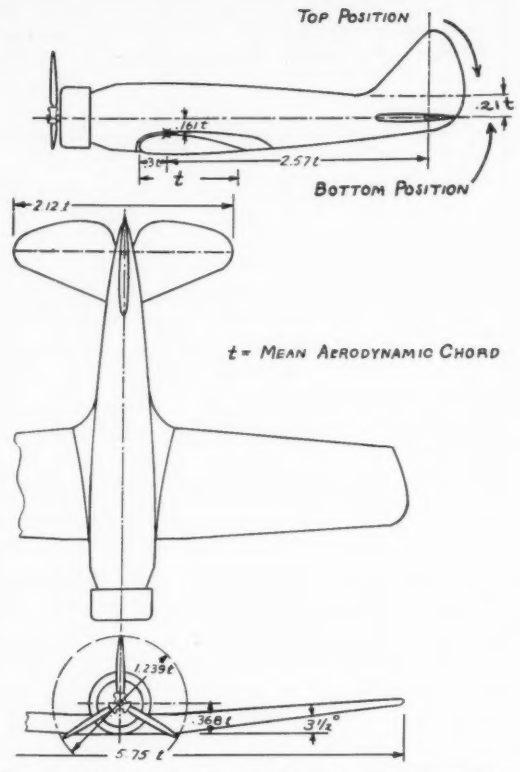


FIG. 3. Diagram of power model with driven propeller.

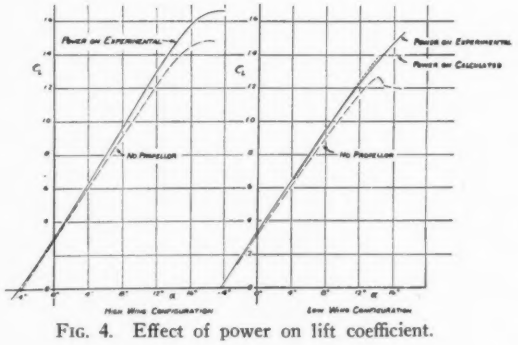


FIG. 4. Effect of power on lift coefficient.

construction were undertaken on a power plant to fit in the fuselage of a 1/6th scale model of a moderate sized single-engined commercial transport. With this model two research problems have now been completed. The first, by Lieutenants Russell and McCoy detailed to the California Institute of Technology by the U. S. Navy and Army respectively, considered the model arranged as a high wing monoplane, and the results have already been published.[3]

[3] J. S. Russell and H. M. McCoy, *Wind Tunnel Tests on a High Wing Monoplane with Running Propeller*, Jour. Aero. Sci. Vol. III, No. 3, p. 73 (1936).

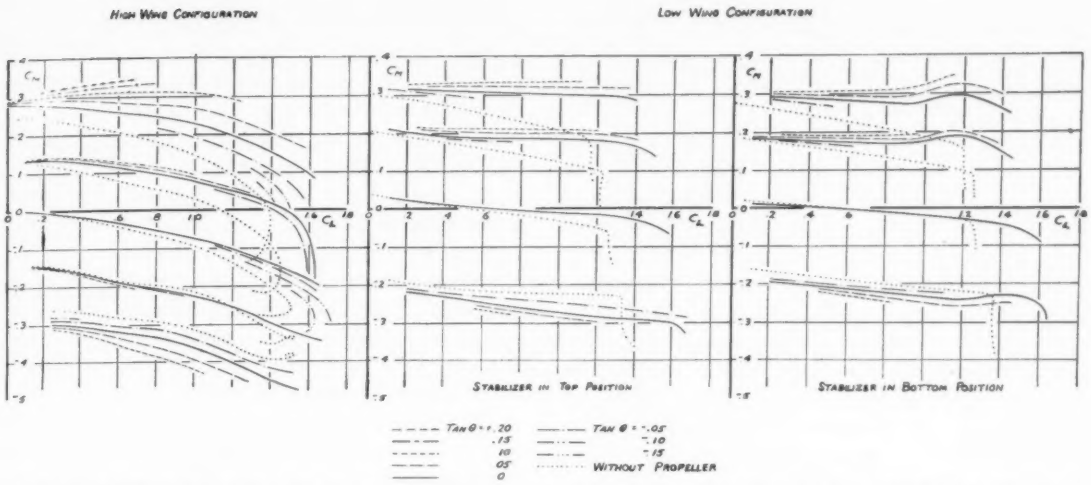


Fig. 5. Effect of power on pitching moment coefficient. Each group of curves for one set of values of Θ represents one elevator setting, the uppermost groups corresponding to full up elevator and the lowest to full down elevator.

The second, by Lieutenant-Commander Bolster and Lieutenant Fleming likewise detailed to the California Institute of Technology by the U. S. Navy, dealt with low wing configurations, and the results have not as yet appeared in print. The author will present a few of the results in order to indicate the nature of the observed phenomena and to emphasize the importance of the problems which remain to be investigated.

In analyzing the data it was found that the most convenient parameter for representing "amount of power" was the angle of climb or glide, denoted by Θ. Accordingly, on the figures curves have been drawn for various constant values of Θ, positive values corresponding to power excess or climbing flight, and negative values to power deficiency or gliding flight.

Fig. 3 gives a diagram of the model arranged as a low wing monoplane. Two vertical locations of the horizontal tail surfaces will be discussed as indicated on the diagram. The high wing tests were made with the same model rearranged to give a conventional high wing monoplane. In the latter tests, the tail surfaces were in the bottom position. All dimensions are given in terms of the mean chord, l.

Fig. 4 gives curves of lift coefficient plotted against angle of attack for the low and high wing configurations, without propeller and with the propeller just overcoming the drag as in level flight. The increase in lift at a given angle and the raising of the stalling angle are very noticeable. For the low wing configuration, the lift increase was calculated, taking into account the vertical component of thrust and the effect of the increased velocity over the portion of the wing in the slipstream. The agreement between the calculated and observed values is quite satisfactory below the stall, but the increase in the angle of attack for maximum lift with power on has not as yet been satisfactorily predicted quantitatively.

Fig. 5 gives pitching moment coefficient as a function of lift coefficient for various configurations. Stalling, or tail heavy moments are taken as positive, so that static stability is indicated by a negative slope, instability by a positive slope. The effects of power are seen to be very pronounced. As elevator angles are increased in the upward direction, the stability is more and more decreased by the application of power, until with large elevator deflections the stability practically vanishes with full power. The elevator effectiveness is marketly increased by the application of power, which result is, of course, in complete agreement with every pilot's observations in flight. The stabilities of the high and low wing configurations cannot be directly compared, since the assumed center of gravity positions were not identical in the two cases. However, the two stabilizer locations with the low wing are comparable, and the curves lead to very interesting conclusions. With the stabilizer in the bottom position, many of the power-on curves indicate a definite instability shortly before the stall. This type of instability has frequently been observed in flight with low wing monoplanes. Moving the stabilizer up to the top position decreases the average stability slightly but almost completely eliminates the sudden instability near the stall. Calculations attempting to explain these complicated influences of power on stability have not as yet proven quantitatively satisfactory.

The sample results which have been discussed show that propeller slipstream has a considerable influence on lift and static stability even for single motored airplanes. For large multi-motored machines, a very large fraction of the wing area is often in the slipstream, so that the effects may well attain an extreme importance. Theoretical calculations are difficult because of interferences which are not easily

amenable to analysis but both theoretical and experimental investigations are planned or under way by several workers in the United States. The new giant wind tunnels, of course, furnish ideal tools for these problems, so that one may expect that great advances in this field will be made within the next few years.

Even more complex than the static stability effects just discussed are the dynamic properties which are popularly classified as flying qualities. One of the greatest difficulties connected with the problem of flying qualities is the fact that there is no uniformity of opinion on the part of operators as to what constitute good characteristics, so that even the ideal towards which the designer should strive is very hazy and uncertain. Furthermore, even when a definite type of objective is agreed upon, there are very few properties to which quantitative numbers can be assigned as representing satisfactory versus unsatisfactory characteristics. Before any very large progress can be made in this field, it is, therefore, clear that a large amount of work must be done by operators, pilots, and designers working in close cooperation. One of the most promising approaches towards such cooperative effort appears to be the following: The purchaser of a proposed new airplane specifies numerical values for as many flying characteristics as he can, the designer then attempts to fulfill these requirements; flight tests on the completed airplane will furnish data on the correlation between design parameters and the various flying properties actually achieved; finally, subsequent experience with the airplane in actual operation will suggest desirable modifications to the numerical values as well as new quantities to be specified for later airplanes. Such a program is obviously a very lengthy and expensive one, but it has actually been inaugurated in at least one case with which the author is familiar. Since, to the best of the author's knowledge, it is the first such program to be undertaken with anything approaching its refinement, the numerical values involved will almost certainly have to be altered in the light of later experience. However, since it does constitute a definite first step upon which later developments may be based, it would appear to have sufficient importance to warrant a little time spent in discussing some of its details. The following, therefore, gives some of the numerical values which have been incorporated in the specifications of a relatively large commercial transport which is now under construction.[4] How closely the designers are able to meet these specifications, and how well the specifications themselves really correspond to desirable flying characteristics will be decided in the later phases of the program when the airplane is test flown and placed in actual operation. The specifications were drawn up by E. P. Warner, for the four-motored Douglas DC-4 transport which is being constructed for five of the principal American airlines.

In general, all of the following specifications must be met at all speeds from 16 km/hr. above minimum to 32 km./hr. above maximum speed of level flight, at all throttle settings and distributions of load, with flaps and landing gear either extended or retracted. The maximum speed with flaps or gear extended is, of course, limited. The requirements divide themselves into several distinct categories under which they are listed below:

Free control behavior

With the plane trimmed at any speed from 160 km./hr. to the maximum speed, it must be possible to leave the controls free with the following results:

(a) In fairly rough air (gust velocities from 1-½ to 2 m./sec.) all regular oscillations shall damp out in not more than three cycles, and the airplane must not maintain continuously for more than 15 seconds an angle of roll or yaw of over 15° or a speed differing from the trimming speed by more than 24 km./hr.

(b) In smooth air (gust velocities less than 1m./sec.) the angle of roll or yaw shall never exceed 10° or the speed differ by more than 16 km./hr. from the trimming speed.

Static Longitudinal Stability

(a) The curve of stick force for steady flight plotted against speed of flight shall be everywhere negative and without discontinuities, or sudden changes in curvature. Its slope must always be numerically less than 0.45 kg. per km./hr.

(b) The curve of elevator angle against speed shall also be smooth and have everywhere a slope of the same sign.

Dynamic Longitudinal Stability

(a) From level flight at any speed between 50% and 100% of maximum velocity with the airplane trimmed, the nose shall be pushed down 10° and held there until the speed has increased 40 km./hr. The stick shall then be released and the resulting motion must be a damped oscillation whose amplitude is decreased to at most 1/5 of its original value within four cycles. The period shall never be less than 35 seconds.

(b) With flaps both up and down at speeds about 16 km./hr. above the corresponding stalling speeds, when the nose is pushed down until the speed has increased 16 km./hr. and the stick then released, there shall be recovery to within 8 km./hr. of the original value within three cycles of oscillation, and the speed must not become low enough to produce marked irregularities in the behavior of the airplane.

Static Directional Stability

(a) The curves of rudder angle and pedal force required for straight flight, when plotted against

[4] In this survey no attempt has been made to follow the exact legal phraseology of the specifications, and certain exceptions for abnormal conditions have been omitted.

eccentric thrust (obtained by varying the thrust of the power plants on the two sides of the airplane) shall be smooth, without any reversals of slope, and without any sudden changes in slope. This must also be true of the curve of angle of yaw versus eccentric thrust.

(b) With sudden application of 10° of aileron, held until a 15° bank is attained which is then maintained for three seconds, the change of heading must be between 1° and 5°. Not over 23 kg. on the rudder or 14 kg. on the elevator shall be required to hold a steady 15° bank without turning.

Dynamic Directional Stability

With rudder deflected 10°, held there until a 10° change of heading is attained, and then released, the heading finally taken shall differ by not more than 5° from that when the control was released. The initial swing in heading shall be not over 12° and the total amplitude shall be reduced to less than 3° within three cycles. The period must be at least 20 seconds. Ailerons shall be used to hold the wings level, and the condition must be satisfied at speeds from 50% to 100% of maximum.

Lateral Stability

(a) With the ailerons released immediately after putting the machine in a 15° bank and keeping zero yaw with the rudder, the angle of bank must be reduced to less than 2° within 15 seconds and with a loss of altitude of not over 100 m. (Near the stall the requirements are a little less stringent). If the motion of recovery is not a simple subsidence, the amplitude of the swing beyond neutral shall not exceed 5°.

(b) With the machine put into any bank up to 45°, with any degree of side-slip, either the neutralizing or the release of rudder and aileron controls shall be followed by at least a gradual decrease in the bank and rate of turn.

Control Characteristics

(a) At 10 km./hr. above stalling speed (with flaps up or down) it shall be possible to change the angle of pitch either up or down by 5° in 1.5 seconds, using only the elevator control.

(b) At 15 km./hr. above stalling speed it shall be possible to produce a change of heading of 10° in 3 seconds by the use of rudder alone.

(c) At 10 km./hr. above stalling speed, it shall be possible to bank the airplane 10° in 3 seconds, using the ailerons alone.

(d) The control forces for all these tests shall not exceed: 35 kg. push or pull on the stick, 70 kg. on the rudder, or 14 kg. applied tangentially to the wheel.

(e) At 15 km./hr. above stalling speed, or at any higher speed, any sudden application of aileron shall produce an acceleration in yaw less than one-tenth of that in roll.

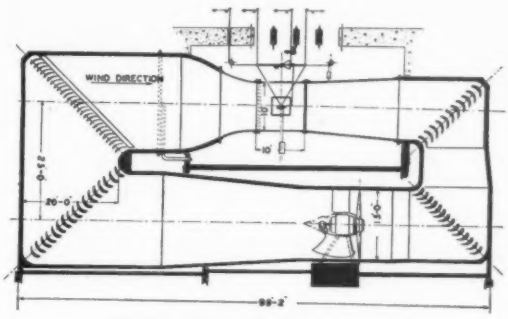


FIG. 6. GALCIT wind tunnel.

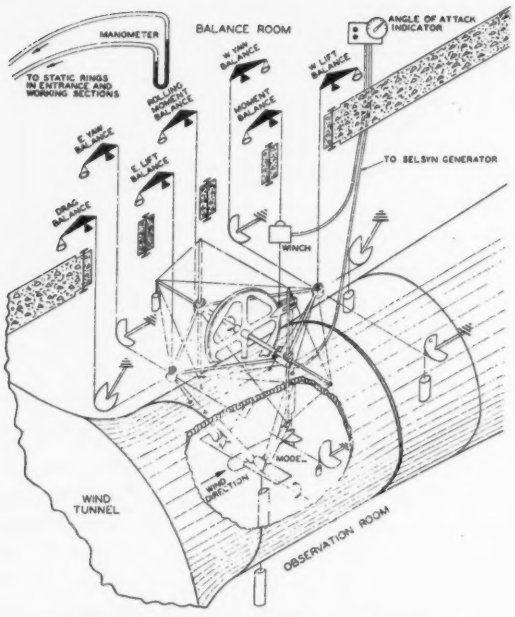
(f) At any speed more than 30 km./hr. above stalling speed, it shall be possible to hold a straight course with all engines on one side of the airplane completely cut out, while those on the other side operate at full rated power. The force on the rudder pedals, with rudder tabs neutral, shall not exceed 90 kg. up to twice the stalling speed. It shall be possible to produce complete trim by the use of the rudder tabs.

(g) In making a turn with 45° bank at 225 km./hr., the forces required shall not exceed 45 kg. on the rudder pedals or 35 kg. on the stick, or 23 kg. applied tangentially to the wheel; these limitations must hold in the steady turn and also in attaining the turn in 5 seconds from level flight.

The above list of specifications does not, by any means, exhaust the numerical requirements which have been applied by E. P. Warner to the airplane in question, but it does give an indication of the detailed manner in which the problem of flying qualities must, in the future, be attacked. It may also serve as a starting point for discussion here.

The second portion of this paper deals with cooperation between independent research laboratories and practical designers and builders of aircraft. As has already been mentioned, the author's remarks will be based almost entirely on his own experience with one such laboratory, and he shall therefore begin with a brief description of its nature.

The wind tunnel (see Fig. 6) is essentially of the Goettingen type, but is normally used with closed working section. The cross-section is circular throughout, the working section being 3 meters in diameter. A 1000 hp. electric motor with a 4.6 meter diameter fan gives a maximum velocity at the working section of about 95 m./sec., although the normal operating velocity is between 80 and 85 m./sec. The automatic balance system permits all six components of force and moment to be measured simultaneously. The normal setup is shown in Fig. 7 which also reveals one of the most serious defects of the system,



SIX COMPONENT SETUP FOR TEN FOOT WIND TUNNEL TESTS
AT GUGGENHEIM AERONAUTICS LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

FIG. 7. Six-component model suspension.

namely that the model cannot be rotated in yaw. As a temporary expedient, the model is mounted with span vertical for yaw tests, but a new suspension system is now being designed which will permit yaw tests to be made simultaneously with normal measurements.

Before proceeding to describe in detail certain of the results which have been obtained during the past few years in the course of investigations the author should like to outline some of the advantages which seem to him to follow from such cooperative activities.

(1) Detailed information relative to specific projects, modifications, etc., can be furnished the designer in the same manner as if the laboratory belonged to the manufacturer. This, of course, requires that company aerodynamicists and designers be present at the tests and take an active part in their carrying out.

(2) Specialized investigations of definite questions confronting a company often lead into broad and general problems having a much wider field of interest than did the original questions. These can then be taken over as research investigations by the laboratory staff with or without the active cooperation of the company. When such problems arise in a company laboratory, it is very seldom that they can be successfully pursued, both because of lack of time of company personnel, and also because it is difficult for a single concern to justify the expenditure involved in research of general rather than specific interest.

(3) As a corollary to the above, the constant contact of the academic members of the laboratory staff with the immediate problems of practical designers has a very beneficial effect upon their research and academic activities, by keeping the latter up-to-date and in the current of actual aeronautical development.

(4) Such a laboratory can serve as a very useful link between the general and exhaustive investigations of large governmental agencies, such as the D.V.L. in Germany and the N.A.C.A. in the United States, and the direct application of their results to individual designs.

(5) The very size and nature of these enormous government agencies make it difficult to break into their carefully prepared schedule of investigations with tests which the designer needs quickly in order to answer specific questions arising in the course of specific designs. Smaller laboratories such as are being discussed will almost inevitably have much more flexibility in this regard.

(6) A certain minimum size and velocity wind tunnel appears to be necessary in order that model results may be satisfactorily extrapolated to full scale. For many problems these lower limits correspond to a Reynold's Number, based on wing chord, of something like one million. Tests made at lower Reynold's Number than this, while useful in certain cases, are frequently of doubtful value. A wind tunnel large and powerful enough to furnish Reynold's Numbers of over a million involves such an investment that few aeronautical companies could afford it. On the other hand an independent research organization financed by initial donations or by a considerable group of companies is usually able to have a wind tunnel giving Reynold's Numbers well over one million. This gives it a very definite advantage over the company laboratory with its necessarily limited equipment.

(7) The cooperating laboratory can collect and compare statistically data from more types of aircraft and more numbers of the same type than could a company laboratory, and the data correspond more closely to practical and advanced designs than could those obtained in a pure research establishment.

(8) Using the data discussed in the paragraph above, the research group can make comparisons with theory, determine empirical correction factors, etc., much more readily than could engineers whose interests were largely tied up with the immediate concerns of a manufacturing company.

(9) Because of its close contacts with numbers of designers, the laboratory forms a very natural meeting place for engineers from various companies and can stimulate extremely useful interchanges of ideas between them.

(10) Finally, from the purely academic point of view, the active presence of designers in connection with their tests and at the seminars is extremely valuable to aeronautical students for reasons which are so obvious as to need no discussion.

TABLE 1
Parasite Drag Added by Fuselage
(based on frontal area)

C_{D_p}	Type of Fuselage or Airplane
0.072	Bare hull of dirigible "Akron" outline, circular cross-section, tested alone
0.070 to 0.105	Large commercial transports, low wing, no nose engine
0.090	Large military airplanes, no nose engine
0.100	Low wing, single-engined transports; nose engine
0.130	Low wing, small airplanes with cockpit enclosure; nose engine

TABLE 2
Parasite Drag Added by Nacelles

C_{D_p}	Type of Nacelle or Airplane
0.250	Nacelle mounted externally above the wing
0.120	Leading edge nacelles, small airplane, relatively large nacelles
0.080	Leading edge nacelles, large airplane, relatively small nacelles

In order that the advantages just enumerated may be fully realized, it is necessary that the laboratory not only furnish numerical data from specific tests requested by a manufacturer, but also act essentially in the role of consulting engineer giving advice based on its previous experience. Such a relation places a considerable burden on the laboratory since it can only succeed if all data are kept absolutely confidential, and if the companies have complete confidence in the disinterestedness and integrity of the laboratory personnel.

In order to demonstrate a few of the actual results of cooperative activities such as have been discussed above, the author will, in the remainder of the paper, give some statistical data which have been collected from several years of testing. He has attempted to choose those subjects upon which a fairly consistent body of information has been acquired and which are of considerable interest to designers. Unless otherwise specified, all numerical values correspond to Reynold's Numbers, based on wing chord, lying between 1.5 and 2.0 million. The turbulence of the wind tunnel air stream is low, the critical Reynold's Number of a 15 cm. sphere being about 330,000.

PARASITE DRAG OF MAJOR AIRPLANE COMPONENTS

(a) *Wing*

Here the parasite drag coefficient is taken as the profile drag coefficient, based on total wing area, calculated assuming elliptic lift distribution. For a large number of tapered, cantilever wings with taper ratios between 2.5 and 3.5 to 1, root thickness between 15% and 18%, tip thickness between 6% and 10%, airfoil family N.A.C.A. 2200, 2400 or 23,000, the average values are about

$$C_{D_p} = \begin{cases} 0.0090 \text{ to } 0.0095 \text{ without ailerons.} \\ 0.0100 \text{ to } 0.0105 \text{ with ailerons.} \end{cases}$$

(b) *Fuselage*

Here the parasite drag coefficient is based on the maximum projected frontal area including any wing area lying inside of the fuselage lines. The interference drag between wing and fuselage is included since the values are obtained from differences between the drag of wing plus fuselage and wing alone. In the case of fuselages with nose engines, the cooling drag is also included since the models were tested with engines and cowls simulating as closely as possible the full scale conditions of airflow through both. All engine models represented air-cooled engines. All models were smoothly finished with no attempt to reproduce rivets, joints, window recesses, etc. Average numerical values, based on a considerable number of modern planes, are given in the Table 1.

The range of values in the second line of Table 1 is rather large; however, nearly all of the fuselages with really streamlined looking lines fall close to the lower limit. Those which approach the upper limit have unusually large fineness ratio, or rather obviously poor lines. Comparing the lower limit with the numerical value for the "ideally streamlined" dirigible shape, it appears that the presence of windshield, etc., just about compensates for the amount of wing frontal area normally included in that of the fuselage. Practically all of the military models tested had good basic fuselage lines and hence should correspond to the lower limit of the large commercial planes. The additional drag represents the aerodynamic penalty which must be payed as a result of the modifications made necessary by special military requirements: armament, visibility, etc. The relatively small drag increment caused by the nose engine mounted on a relatively large fuselage is very interesting, as is the high drag of a small plane fuselage with cockpit enclosure protruding above the normal fuselage upper surface.

TABLE 3

Parasite Drag Added by Tail Surfaces

C_{D_p}	Description of Airplane Type
0.0085 to 0.0120	Single-engined, low wing monoplane
0.0060 to 0.0110	Multi-engined, low wing monoplane
0.0120 to 0.0180	High wing monoplane or biplane

(c) *Engine Nacelles*

All nacelle drags given below include interference effects and are based on total frontal area as in the case of fuselages. All correspond to radial engines with N.A.C.A. type cowling. The results have been divided into three categories in Table 2.

The result for nacelles above the wing is based on relatively few models and serves chiefly to show the very large drag which such a configuration causes. The dividing line between the second and third categories is obviously a rather hazy one, but, with the limited number of sizes of existing radial engines with sufficient power to be used in contemporary commercial or military multi-motored aircraft, the two classes appear very definitely in the experimental data.

(d) *Tail Surfaces*

Here the experimental values have a very large scatter due probably to the very different amounts of fuselage and wing interference on the tail for various designs. The drag coefficients of Table 3 are based on the tail surface area outside of the fuselage, and are determined at the angle of attack where the lift on the tail is zero. They are chiefly interesting as furnishing orders of magnitude.

STATIC LONGITUDINAL STABILITY AND CONTROL

(a) *Downwash at the Tail*

For several years the author has used a very simple formula for calculating pitching moment due to horizontal tail surfaces, without engine power. This formula is based on two fundamental assumptions, namely that the lift distribution over wing and tail is elliptical. and that the downwash at the tail due to the wing has the value which the simple, first order wing theory would give at an infinite distance downstream, i.e. twice that at the wing. An empirical, multiplicative reduction factor, called the tail efficiency factor, is also introduced to account for the slowing down of the air over the tail surfaces due to wing, fuselage, etc., interference. It has been felt that the complexity of the interference effects introduced so many uncertainties that more elaborate assumptions as to downwash were not necessary or useful. By comparing the experimental effects of changes in tail setting and in angle of attack, it is possible to determine the actual downwash (assuming the validity of the conventional formula for lift curve slope) and so to find the ratio of the latter to the value assumed. A large number of tests on modern, low wing monoplanes gave values for this ratio lying between 0.91 and 1.07, averaging almost exactly 1.00. A few results lay outside this range, but they clearly corresponded to unusual interference effects which could not be taken into account in any formula. It seems, therefore, that the simple downwash assumption is adequate, at least for modern low wing monoplanes.

(b) *Tail Efficiency Factor*

The tail efficiency factor described above depends on fuselage shape, tail location, wing location, tail shape, nacelle configuration, etc., and must therefore vary widely from plane to plane. However, for a large number of low wing monoplanes, the values determined experimentally varied only between 0.61 and 0.75 with an average of about 0.68. These numerical values are obtained by comparing actual tail moments with those calculated neglecting the tail efficiency factor. For airplanes of the type considered, it would seem that 0.65 should be a safe figure on which to base preliminary designs. For high wing monoplanes, the tail efficiency is usually somewhat higher, probably because of the less unfavorable wing-tail interference.

(c) *Directional Stability and Rudder Control*

In the following the usual absolute yawing moment coefficient, C_v, is employed, based on dynamic pressure and the product of wing area and span. If Ψ represents angle of yaw, then for satisfactory directional stability, it appears that the slope of the yawing moment curve versus angle of yaw, $dC_v/d\Psi$, should be approximately constant for angles of yaw less than 15°. All of the airplanes tested in the California Institute of Technology laboratory and whose directional characteristics in flight are known to be satisfactory, have had values of $dC_v/d\Psi$ between –0.0009 and –0.0014, with the American convention for signs. Certain models with smaller numerical values are known to have led to unsatisfactory results in full scale flight tests, while larger values would probably also lead to bad directional characteristics or to spiral instability. In general, the smaller, more maneuverable airplanes lie close to the numerically smaller limit, while large machines approach the larger limit.

Rudder effectiveness may be measured both by the change in yawing moment per degree of rudder deflection at small angles of yaw or rudder deflection, and by the maximum yawing moment produced by full rudder throw, also at small angles of yaw. For the former, the experimental values obtained (with models of satisfactory planes) lie between 0.0006 and about 0.0010, the smaller rudder effectiveness usually occurring for the models with smaller directional stability and vice versa. The maximum yawing moment coefficient for full rudder throw at zero yaw lies very close to 0.020 for practically all of the models of satisfactory airplanes tested. A few attain values as high as 0.030, but this is almost certainly unnecessarily large, except possibly to insure control during take-off in the case of engine failure on multi-motored aircraft.

(d) *Aileron Control*

Since ailerons are almost always operated differentially today, it is impossible to define aileron effectiveness in terms of the rolling moment per degree of deflection. Aileron control may, however, be specified by the maximum rolling moment coefficient for full aileron deflection, which quantity is usually nearly independent of angle of attack until the neighborhood of the stall. The coefficient, C_r, is defined exactly as is the yawing moment coefficient in terms of the product of dynamic pressure, wing area, and span. The available data are somewhat more meager than was the case for yawing moment, but they indicate maximum rolling moment coefficients due to aileron throw lying in general between 0.030 and 0.040. An interesting fact is that there is no indication that small, maneuverable planes have any consistently larger values than do large multi-engined transports. The former, of course, have relatively much smaller moments of inertia about the longitudinal axis, so that their response to a given rolling moment coefficient is more rapid than would be the case if they were simply scaled-down versions of the larger machines.

(e) *Control Hinge Moments*

The final topic which the author wishes to mention is that of hinge moments. The enormously increased importance of this question as airplane sizes grow has already been pointed out. It is probably not an exaggeration to state that almost the most difficult problem of the aerodynamicist, in connection with the very large planes now being designed, is the design of effective control surfaces whose hinge moments will be such that the controls can still be manually operated. The C.I.T. laboratory has already undertaken several elaborate investigations into the matter, but the surface has as yet only been scratched. Much further wind tunnel work must be done and a great deal of correlated flight testing carried on since dynamic questions are often of major importance. Unfortunately, these experiments are as yet confidential so that the author cannot furnish any numerical data. One general conclusion may, however, be of some interest. These measurements have not shown any possibility of obtaining satisfactory hinge moments for extremely large surfaces at all angles of attack and control settings by means of fixed aerodynamic balance ahead of the hinge line. In the future when giant planes are built, it appears that the only way of avoiding motor driven controls is through the use of some sort of variable aerodynamic balance such as servo tabs with a complicated differential control system.

Conclusion

In the course of the above remarks, the author has attempted first to present a few of the aerodynamic problems which are of current interest in the United States, and second to discuss the cooperation which has, at least in some cases, proven beneficial, between manufacturing companies and independent research organizations, together with a few sample results of such cooperation. He hopes that the rather unexciting numerical data given may serve as a starting point for later discussion, and more importantly may stimulate the presentation of analogous data from other sources. For it is only by the free interchange of ideas and results between different groups, especially those working far apart and in different countries, that a new subject like aeronautics can receive its fullest development.

Natural Vibration Frequencies of Structural Members as an Indication of End Fixity and Magnitude of Stress

BOYD C. STEPHENS, *University of Minnesota*

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Introduction

IN this paper an experimental method for the determination of the degree of end restraint of structural members is presented together with a method for determining the magnitude of load in an axially loaded member by means of a single easily made measurement on the member as it stands in the stressed conditions.

These two unknowns are made determinable by the fact that the natural vibration frequency of a structural member is a definite function of both the degree of end restraint and the axial load existing in the member. With this established it remains to determine the actual relations existing between first, the natural vibration frequency and the end restraint of the member, and, second, the natural vibration frequency and the axial load in the member.

Nomenclature

P ....total axial load in the member { + when compressive, − when tensile }
P_{eu} ..Euler buckling load (lb.).
E ....Young's modulus (lb./in.^{2}).
I ....moment of inertia (in.^{4}).
A ....area of cross section of member (in.^{2}).
l ....length of member (in.).
γ ....density of material (lb./in.^{3}). = 0.2833 for steel
g ....acceleration of gravity (in./sec.^{2}). = 386. approximately.
f ....frequency of natural vibration (cyc./sec.).
f_o ....frequency of natural vibration at zero load (cyc./sec.).
K ....a constant in the frequency equation depending on the degree of end restraint.
c ....a coefficient in Euler's bucking equation and is a measure of end restraint.
x ....distance from origin to any point on the member.
y ....deflection of member from equilibrium position at any point (x).
u ....a function of x determining the shape of the deflection curve.
p ....pulsatance defined as $2\pi f$.
V_p ....potential energy due to bending.
V_b ....potential energy due to axial load.
T ....kinetic energy of the vibrating member.

Determination of End Fixities of Structural Members

The coefficient in common use expressing the degree of end restraint of a structural member is the constant c in the basic Euler buckling equation.

$$P_{eu} = \frac{c\pi^2 EI}{l^2}. \tag{1}$$

The coefficient c is theoretically determinable for four different types of end restraint, one method used being simply to equate the potential energy of bending to the change in potential energy of the axial load.[1]

To correlate the degree of end restraint with the natural vibration frequency, it is necessary to investigate the transverse vibration of bars and to determine the frequency equations for the same four types of end restraint. This has been done by Timoshenko[2] in the following briefly outlined manner.

To obtain the vibration equations of deflection and frequency, D'Alembert's[3] principle may be used, and the bar may be considered loaded transversely with inertia forces. Rotary inertia may be justifiably neglected for the small deflections encountered in a vibrating bar. Deflections due to shear need not be considered as long as only the fundamental mode of vibration is to be used except in latticed struts where shear deflections are large.

The inertia forces considered as an intensity of loading may be expressed as

$$-\frac{\gamma A}{g}\frac{\partial^2 y}{\partial t^2}$$

which may by the basic flexure theory of bending be equated to

$$EI\frac{\partial^4 y}{\partial x^4},$$

which gives

$$a^2\frac{\partial^4 y}{\partial x^4} + \frac{\partial^2 y}{\partial t^2} = 0 \tag{2}$$

[1] S. Timoshenko, *Strength of Materials, Part II.* D. Van Nostrand Company. 1930.
[2] S. Timoshenko. *Vibration Problems in Engineering.* D. Van Nostrand Company. 1928.
[3] D'Alembert's principle states that the resultant of effective forces for all particles of a body, if reversed and assumed to act on the body with the external forces, will hold the body in equilibrium.

where

$$a^2 = \frac{EIg}{A\gamma}. \tag{3}$$

When the bar vibrates, its deflection at any point varies harmonically with the time as well as being a function of the distance along the bar so that one may write

$$y = u\,(A \cos pt + B \sin pt) \tag{4}$$

where u as a function of x and p is defined as $p = 2\pi f_0$.

Differentiating Eq. (4) four times with respect to x and twice with respect to t and substituting in the differential Eq. (2), gives

$$\frac{d^4u}{dx^4} = \frac{p^2}{a^2}\,u \tag{5}$$

which may be solved for u.

Calling

$$k^4 = \frac{p^2}{a^2}, \tag{6}$$

the solution of the differential Eq. (5) may be put in the form

$$u = C_1\,(\cos kx + \cosh kx) + C_2\,(\cos kx - \cosh kx) + C_3\,(\sin kx + \sinh kx) + C_4\,(\sin kx - \sinh kx) \tag{7}$$

The constants C_1, C_2, C_3, and C_4 are determined for each type of end restraint by the known end conditions. As an example, for the case of one end fixed and one end free, the end conditions are

$$(u)_{x=0}=0 \qquad \left(\frac{d^2u}{dx^2}\right)_{x=l}=0$$

$$\left(\frac{du}{dx}\right)_{x=0}=0 \qquad \left(\frac{d^3u}{dx^3}\right)_{x=l}=0$$

which when substituted in Eq. (7) give the frequency equation

$$\cos kl \cosh kl = -1 \tag{8}$$

whose first root value of kl is 1.875.

Similarly, frequency equations for the other three types of end restraint may be derived and are tabulated in Table 1.

TABLE 1

Type of End Restraint	Frequency Equation	First root value of (kl)
One end fixed, one end free	$\cos kl \cosh kl = -1$.	1.875
Both ends pinned	$\sin kl = 0$	π
One end fixed, one end pinned	$\tan kl = \tanh kl$	3.927
Both ends fixed	$\cos kl \cosh kl = 1$	4.730

Since by Eq. (6) $k^2 = p/a$, and $f_0 = p/2\pi$,

$$f_0 = \frac{Ka}{2\pi l^2} \tag{9}$$

where $K = (kl)^2$ and has the values given in Table 2. Corresponding values of the end fixity coefficient are given in the same table.

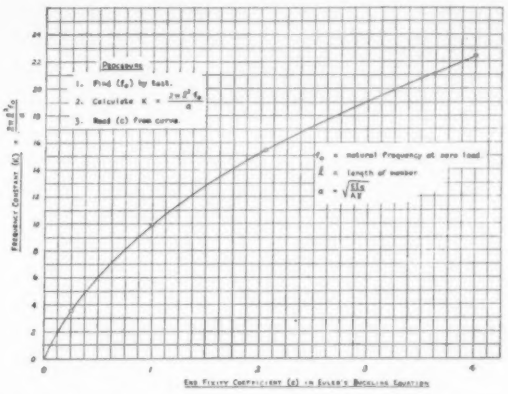
Procedure
1. Find (f_0) by test.
2. Calculate K =
3. Read (c) from curve.
f_0 = natural frequency at zero load
l = length of member
a =
End Fixity Coefficient (c) in Euler's Buckling Equation

FIG. 1. Curve for use with experimental values of frequency f_0 in finding end fixity coefficient c.

TABLE 2

Type of End Restraint	c	K
One end fixed, one end free	¼	3.516
Both ends pinned	1	9.870
One end fixed, one end pinned	2.047	15.421
Both ends fixed	4	22.373

If values of K are plotted against corresponding values of c, the curve of Fig. 1 is obtained, which is found to be a smooth curve passing through the origin.

Thus the four theoretically determinable values of c and K make possible a curve which gives a *continuous* relation between c and K, which means a continuous relation between the degree of end restraint with which a member is held and the natural vibration frequency of the member.

Thus to determine the degree of end restraint of a member it is only necessary to determine the natural vibration frequency by test, after which K may be determined by Eq. (9). Then going to Fig. 1, the corresponding value of c which is the measure of end fixity may be found.

Justification for drawing a continuous curve (Fig. 1) through the four determinable points may be seen from a consideration of the energy involved in a vibrating bar. During a quarter of a complete cycle of vibration all the potential energy of bending in the bar is converted to kinetic energy—likewise for successive quarter cycles. Thus the total potential energy of bending equals the total kinetic energy of motion. This law is true for any degree of end restraint. It can be shown that the deflection of any point of a bar restrained in the same way at both ends becomes continuously less as the degree of end restraint increases continuously from the case of pinned ends to the case of fixed ends. Also the potential energy of bending changes continuously with change in end restraint as long as the same forces are acting on the bar. Hence in order that the kinetic energy of the vibrating bar may equal the po-

tential energy, the frequency of vibration must change continuously as increasing and restraint reduces the deflections of the bar. This reasoning justifies the drawing of a continuous curve through the four determinable points of Fig. 1.

There are a number of limitations which must be imposed on this method for determining end fixity experimentally. These restrictions may be listed as follows:

(1) No adjoining members may partake appreciably of the vibration of the member in question. Therefore, to extend the method to members of a rigid or semi-rigid frame, the vibration energy of all members affected must be taken into account. Further study on this problem is required.

(2) Only the member being tested should vibrate, massive ends such as a ball and socket sometimes used in testing columns cannot be used.

(3) No transverse loads may be acting on the member.

(4) There should be no bending stress in the member.

(5) There should be no axial load greater than about 1% of the bucking load in the member. If there is an axial load in the member, the method given later under "Determination of End Fixity with a Known Load in the Member" should be used.

(6) The member must be straight and of uniform section.

A modified conception of the fixity coefficient (c) in Euler's buckling equation (Eq. 1) is made necessary in the case of long thin tension members because of our assumption of the sinusoidal form of deflection curve in deriving Eqs. (1) and (9). In this type of member an end fixity cofficient is of no value in itself; however it is necessary in the following work where loads existing in such members are predicted from the vibration frequency measurement.

Vibrating wires with pin connected ends have a deflection curve of the sine form, the length being one half wave. The same is true for a pin connected column even in the short column range. Hence it can be seen that as long as the ends are pin connected the form of the deflection curve is not affected by the rigidity of the member. However if the ends are fixed, the rigidity of the member affects the sine form of deflection curve. For columns in the long or short column range the curve is a pure sine wave of one whole wave length, but as the rigidity is decreased and the member becomes more like a flexible wire, the sine form is lost and gradually approaches a one half wave sinusoidal form with distorted ends. Thus in the case of very long thin members or wires where rigidity becomes very small, an end fixity coefficient of 4 could not be expected by the frequency method even though the ends are rigidly fixed. Instead, the frequency method gives a modified value of c only slightly greater than that for pinned end ($c = 1$). The same reasoning applies to any long thin member whose ends are restrained to some degree between perfect fixity and perfect freedom for end rotation.

TABLE 3

Type of End Restraint	End Fixity Coef. (c)		Predicted Buckling Loads (lb.)		Buckling by test (lb.)
	Euler theory	By freq. method	Using Euler (c)	Using (c) found by freq. method	
Fixed-fixed.....	4	4.000	2088	2088	2040
Fixed-free.....	¼	0.250	17.5	17.5	18
Pinned-pinned.....	1	1.015	35.8	36.3	37
Pinned-rubber socket	.....	1.260	....	45.0	46.5
Fixed-pinned.....	2.047	2.075	79.4	80.3	81.7
Fixed-rubber socket .	.....	2.40	.....	93.7	95.0

Thus the modified value of c found by the frequency method will be a function not only of end restraint but of rigidity. For this reason the modified value of c as found by the frequency method will continue to give true theoretical Euler buckling loads in Eq. (1) even in the long thin members where the sinusoidal form of deflection curve is lost.

Hence, as will be seen further on where the loads in wires or tie rods are predicted by the frequency method, the modified value of c becomes a correction for both rigidity and end restraint.

Experimental work has been done to verify the theory. Long columns of various sizes were tested. The member was set in the testing machine, caused to vibrate by a tap of the hand, and the natural frequency measured with a neon light stroboscope. Long columns were used so that an additional check was provided by comparing theoretical Euler buckling loads using the value of c determined by the frequency method with the actual buckling load by test. Results are tabulated in Table 3.

The first check on the validity of the frequency method of determining the coefficient of end fixity c is provided by the close check of theoretical Euler values of the coefficient c with the values of c obtained by the frequency method. It will be noticed that in cases where one or both ends of the column are pin connected, the value of c obtained by the frequency method is slightly greater than the theoretical Euler value of c. This is to be expected because the pinned end cannot be perfectly pinned and there is some resistance to rotation which would increase the fixity coefficient slightly.

The second check on the frequency method of determining the end fixity coefficient is provided by the fact that the theoretical buckling loads by Eq. (1) using the value of c obtained by the frequency method are closer to the actual buckling loads by test than the

TABLE 4

Type of End Restraint	m
Both ends pinned	1
One end fixed, one end pinned	1.035
Both ends fixed	1.063

theoretical buckling loads using the values of c given by the Euler theory.

FREQUENCY METHOD FOR DETERMINING LOADS IN AXIALLY STRESSED MEMBERS

Because the natural vibration frequency of a structural member varies continuously and rapidly with the axial load existing, it is possible to determine the axial load in a member with considerable accuracy by determining the natural frequency of the member in the stressed condition. Since vibration frequency varies, as has just been shown, with the degree of end restraint, it is necessary to know or first determine the end fixity coefficient before the magnitude of axial load can be established from a frequency measurement.

It has been found that the relation existing between axial load and vibration frequency changes slightly as the degree of end restraint changes; hence this relation has been found separately for the four types of end restraint previously used. From these four different relations it is possible to write a general relation for any degree of end restraint by including an additional constant in the equation, a constant which depends only on the coefficient of end fixity.

By equating the maximum potential energy of bending and compression to the maximum kinetic energy of the vibrating member, the equation expressing the variation of frequency with axial load has been derived.[2]

For the case of both ends pinned, the deflection curve obtained by substituting the known end conditions into the general vibration equation (Eq. 7) is found to be for the first mode of vibration[2]

$$u = D \sin \frac{\pi x}{l} \tag{10}$$

The expression for y is obtained by including a term

$$q = A \cos pt$$

which varies harmonically with time, giving,

$$y = qD \sin \frac{\pi x}{l} \tag{11}$$

From Eq. (11), energy equations are found to be

$$V_b(\max) = \frac{EID^2\pi^4}{4l^3} \tag{12}$$

$$V_p(\max) = -\frac{PD^2\pi^2}{4l} \tag{13}$$

$$T(\max) = \frac{A\gamma D^2 p^2 l}{4g} \tag{14}$$

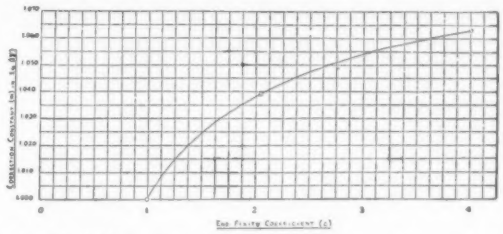

FIG. 2. Variation of correction constant m with end fixity coefficient c.

Equating potential to kinetic energy in their maximum conditions,

$$f = p/2\pi = \frac{\pi^2 a}{2\pi l^2}\sqrt{1 - \frac{Pl^2}{\pi^2 EI}} \tag{15}$$

which may be put into the form

$$P = P_{eu}\left[1 - \left(\frac{f}{f_0}\right)^2\right] \tag{16}$$

When the end conditions are other than pinned, an exact solution is not practical because of the complexity of the expression for y, so to avoid this difficulty, equations similar to Eq. (16) were derived using Rayleigh's approximate energy method, assuming an algebraic deflection curve of suitable form.[4]

The error introduced by using Rayleigh's approximation is negligible for this particular application, being, for the case of pinned ends, about 0.1%.

This has been done, the results making possible the writing of a general equation which holds for any type of end restraint. This equation appears below and contains a constant (m) which varies with the end restraint.

$$P = mP_{eu}\left[1 - \left(\frac{f}{f_0}\right)^2\right] \tag{17}$$

where P_{eu} and f_0 are determined by Eqs. (1) and (9) respectively and depend on the degree of end restraint, and where m has the values given in Table 4.

If values of m are plotted against corresponding values of c for these three end conditions, the curve of Fig. 2 is obtained which shows that the constant m depends on the end conditions.

Hence when the degree of end restraint is known or has been determined by the method outlined previously in this paper, the constant c and therefore P_{eu} is known, the constant K is determined from Fig. 1 and f_0 is obtained by Eq. (9), and finally the constant m is determined from Fig. 2.

Thus, in Eq. (17), values of m, P_{eu}, and f_0 are determined entirely by the degree of end restraint, and when f is determined by test on the member in the loaded condition, the load P existing can be calculated by means of Eq. (17).

[4] Lord Rayleigh, *Theory of Sound*, Vol. 1. Macmillan Co., 1877.

Determination of End Fixity with a Known Load in the Member

The method for determining the coefficient of end restraint as given previously in this paper was subject to the restriction that there be no load in the member when the test is made; however, having established the relation between frequency and load (Eq. 17), it is possible to determine the end fixity coefficient when there is a load of known magnitude in the member.

By substituting in Eq. (17) the values of f_0 and P_{eu} as given by Eqs. (9) and (1), the following equation is obtained:

$$c = \frac{Pl^2a^2}{m\pi^2EI}\left[\frac{K^2}{K^2a^2 - 4\pi^2l^4f^2}\right] \qquad (18)$$

In this equation P is known and f is determined by test. The constants c, K, and m are all interrelated and the equation is solved for c by simultaneous graphical solution with the curve of Fig. 1. To do this it is necessary to assume a number of values of K and the corresponding values of m and calculate values of c by Eq. (18). When these values of K and c are plotted on Fig. 1, an intersection is obtained where both Eq. (18) and the relation between c and K as given by Fig. 1 are satisfied. The value of c at the intersection is therefore the required solution.

Experimental Verification of Theory

If for any member, frequency readings are taken at a number of different known loads and the frequency of vibration is plotted against the load, the resulting curve will be the actual relationship existing between frequency and load. Then by means of Eq. (17) a theoretical curve between frequency and load can be drawn for the same member knowing only the frequency and the physical properties of the member. If the two curves coincide closely enough to be within experimental error, the theory will have been proved.

Test on a Fixed Ended Column

Material

Chrome molybdenum round steel tube with attached end plates to obtain the fixed ended condition.

Geometric and Physical Properties

Length = 39.13 in.
Diameter = ⅝ in.
Thickness = .035 in.
Young's Modulus (E) = 29×10^6 lb./in.^{2}
Moment of inertia (I) = .002833 in.^{4}
Area of cross-section (A) = .06487 in.^{2}
Density of material (γ) = 0.2833 lb./in.^{3}

$$a = \sqrt{\frac{EIg}{A\gamma}} = 41550.$$

g = acceleration of gravity = 386. in./sec.^{2}

Table 5

Run No.	Load (P) in lb.	Vibration frequency (f) cycles/second
1	20	96.6
2	400	87.5
3	800	77.5
4	1200	66.7
5	1390	60.0
6	1600	53.4

Table 6

Load ($-P$) in lb.	Vibration frequency (f) cycles per minute
55	1224
100	1594
195	2190
300	2680
400	3100
500	3460
600	3750
700	4040
800	4310
900	4576
1000	4790
1100	5024
1200	5230
1300	5520
1400	5720
1600	6100
1800	6450
2000	6740

Procedure

The column with attached end plates was placed in a testing machine and lined up vertically by means of spirit levels. Readings of frequency were taken at loads ranging from 20 to 1600 lb. by means of a neon light stroboscope. The data are given in Table 5.

Calculations

By test
$f_0 = 96.6$ cyc./sec. (consider 20 lb. load negligible)
By Eq. (9)

$$K = \frac{2\pi l^2 f_0}{a} = \frac{2\pi\,(39.13)^2\,96.6}{41550} = 22.36$$

From Fig. 1,
End Fixity Coefficient $c = 4.00$ —
By Eq. (1),

$$P_{eu} = \frac{c\pi^2EI}{l^2} = \frac{4.00\pi^2(29\times 10^6)\,.002833}{(39.13)^2} = 2118 \text{ lb.}$$

From Fig. 2, for $c = 4.00$,
Correction to P_{eu}, $m = 1.063$.
Substituting f_0, P_{eu} and m values in Eq. (17),

$$P = 2250 - \frac{f^2}{4.15}$$

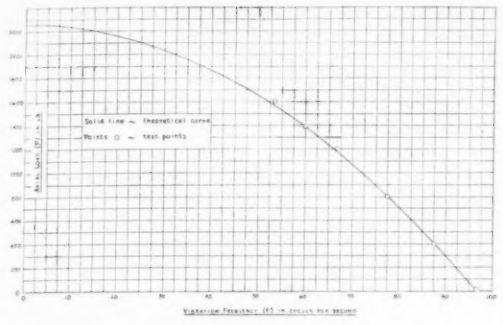

FIG. 3. Variation of frequency with load—fixed ended column.

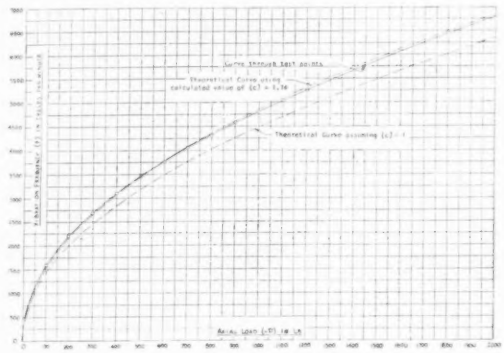

FIG. 4. Variation of frequency with load—fixed ended tie rod.

This is the theoretical variation of load with frequency and is plotted in Fig. 3 as the solid line. The observed variation of load with frequency is also plotted, the points being indicated by small circles. This test shows a very close agreement with the theoretical curve and is a strong argument in the verification of the theory.

TEST ON A FIXED ENDED TIE ROD

Material

Lenticular shaped tie rod with ends suitable for clamping.

Geometric and Physical Properties

Length = 49.375 in.
Young's Modulus, $E = 30 \times 10^6$ lb./in.^{2}
Moment of inertia, $I = 9.48 \times 10^{-6}$ in.^{4}
Weight per unit length, $A\gamma = .00711$ lb./in.

$$a = \sqrt{\frac{EIg}{A\gamma}} = 3930.$$

Procedure

The procedure followed was in general the same as the procedure for the fixed ended column. Fixed ends were obtained by clamping the ends of the tie rod in the tension clamps of the testing machine. Readings were taken at loads from 55 lb. to 2000 lb. The data are shown in Table 6.

Calculations

To determine the modified end fixity coefficient which may be regarded as a correction both for rigidity and for end restraint, Eq. (18) was used, for which the following data were known:

Using one reading arbitrarily,

$P = -1600$ lb.
$f = 6100/60 = 101.7$ cyc./sec.
$m = 1$, since this small correction can be neglected for wires and tie rods.

Then by Eq. (18),

$$c = \frac{214.4\,K^2}{24200 - 0.1546\,K^2}$$

This equation plotted on Fig. 1 gives an intersection with the curve representing the relation between c and K at the point

$$c = 1.74$$
$$K = 14.0$$

By Eqs. (1) and (9),

$$P_{cu} = 2.01 \text{ lb.}$$
$$f_0 = 216 \text{ cyc./min.}$$

and Eq. (17) becomes

$$P = 2.01 - \frac{f^2}{23200}$$

This is the theoretical variation of load with frequency and is plotted in Fig. 4. The test points obtained are also plotted and the curve through the points drawn (solid line).

These curves show a very close agreement between the actual and the theoretical curves. For comparison the theoretical curve assuming the fixity coefficient c equal to unity is plotted. The difference between the curves for $c = 1$ and for $c = 1.74$ shows the effect of fixing the ends.

SUMMARY AND CONCLUSIONS

This paper sets forth a method by means of which the coefficient of end fixity of structural members can be obtained by determining the natural frequency of vibration. This is made possible because of the continuous relation between frequency of vibration and degree of end fixity for any given member which has been established. This continuous relation was built up from calculable relations at four definite points and is indicated in Fig. 1. The method is subject to the restrictions given previously. The theory was verified satisfactorily by experimental work on a number of columns.

Further, theory has been developed and verified by experimental tests, by means of which, knowing or having determined the coefficient of end fixity, loads existing in axially stressed members, either tension or compression, may be determined closely about (2% error) by a single physical measurement on the member in the

stressed condition. This measurement is the natural vibration frequency of the member in the stressed condition. Experimental tests on columns and tie rods were performed, the results of which bear out the theory.

The results of this investigation seem to justify further investigation into the practical uses to which the measurement of natural vibration frequency may be applied in structural problems.

Possible applications of this measurement are many. It might be applied in cases of struts and columns where the coefficient of end restraint is often an unknown quantity. It may possibly prove useful in the determination of applied loads to structures such as aircraft where this quantity is controversial. The method might be used to check loads in certain types of structural members, or to determine effective moment of inertia of complex girder sections.

It is hoped that this article will stimulate interest and further work on the subject.

The writer wishes to express thanks to Joseph A. Wise, Assistant Professor of Structural Engineering, University of Minnesota, for valuable suggestions.

Airplane Longitudinal Stability — A Résumé

ARTHUR G. B. METCALF, *Boston University*

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Introduction

MORE than twenty-five years ago, a rational method of calculating the stability of airplanes was developed by Bryan and published in his *Stability in Aviation*. He laid the ground so well that in the main, no fundamental change in the method has appeared since. However, aerodynamic phenomena, well-understood at present, were not amenable to close evaluation at the time the method was first presented. It was, therefore, exceedingly difficult to predict the behavior of airplanes, when the calculation of the quantities to be substituted in the stability equations was, at best, uncertain.

In the intervening time, research workers have, along with the general progress of aerodynamic science, developed improved methods of evaluating the so-called stability derivatives, on which the calculations rest. This has resulted in placing stability calculation, for the region below the stall at least, on a practical basis. Although the theory is based on the assumption of infinitesimally small disturbances, experience has demonstrated that stability may be predicted relative to disturbances normally experienced by an airplane in steady flight with sufficient precision for all practical purposes.

The application of stability theory to the design of airplanes was pioneered in this country by Hunsaker whose work[1, 2] pointed out the desirability and practicability of such computation as early as 1915. Since that time the method has languished and the airplane designer has made little use of the only existent means of stability analysis which bears any relation to reality. Indeed, he is usually only vaguely aware of "dynamic" stability as "something you don't have to worry about." However, in justice to the designer, it must be said that should he attempt to undertake such an analysis, it would be necessary for him, in order to obtain the required data, to search through a great many technical books and reports, only some of which are useful, and all couched in unfamiliar language. Further than this, such data are usually presented in a form not immediately applicable to the airplane designer's needs. The designer is usually content to insure that the airplane has a degree of "static" stability, determined by the slope of the pitching moment curve as measured on a model fixed rigidly in the wind tunnel. This artificial concept, lacking anything else, may be justifiable, since the presence of some degree of "static" stability *usually* will insure that the airplane upon being disturbed will return, in one way or another, toward the equilibrium position in some oscillatory manner.

At the present stage of aeronautical development it would seem to be high time to discard convenient fictions and to place the stability analysis of airplanes upon a basis as rational, at least, as that of structural analysis. The first step in this direction is to recognize that there is only one "kind" of stability and that it is concerned with the oscillation resulting from a disturbance causing a departure from an equilibrium position. The mere insurance of an oscillatory motion is not enough. It is also essential that the motion be effectively damped, in which connection the period and the damping times are all-important factors.

The first part of this paper concerns itself with a brief résumé of the theory underlying the longitudinal analysis and a description of the non-dimensional stability derivatives, since it is believed that this material in concise form will be useful to designers.

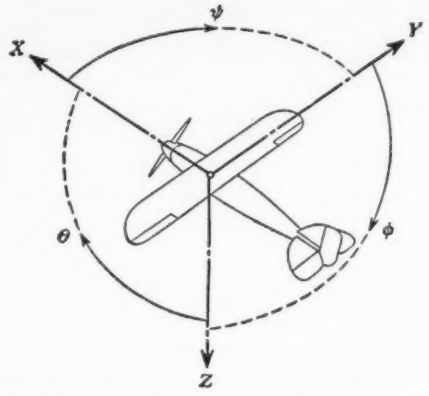
The second part offers expressions for calculating the basic quantities from familiar design data and illustrates the use of the method. An analysis is made for a typical airplane, and the stability is described in terms of the period and the damping.

It should be stated that this presentation is the result of a rather wide examination of available information on the subject, and an attempt has been made to present the data in the most usable form. In this connection, the writer wishes to acknowledge that he has been much assisted by his association with O. C. Koppen who has done a great deal to further develop the method in the form given here for his classes in Airplane Design at the Massachusetts Institute of Technology. The Reports and Memoranda of the Aeronautical Research Committee of Great Britain also provided much useful material. In order to avoid excessive documentation a brief listing of useful texts is given at the end of the discussion.

A more extensive bibliography may be found in W. F. Durand's *Aerodynamic Theory*, Vol. V; Division N, *"Dynamics of the Airplane,"* by B. M. Woods. Julius Springer, Berlin, 1935.

[1] J. C. Hunsaker, *Experimental Analysis of Inherent Longitudinal Stability for a Typical Biplane*, Report No. 1, N. A. C. A., 1915.

[2] J. C. Hunsaker, *Dynamical Stability of Aeroplanes*, Smithsonian Misc. Coll., Washington, 1916.



Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	rolling	L	$Y \longrightarrow Z$	roll	ϕ	u	p
Lateral	Y	Y	pitching	M	$Z \longrightarrow X$	pitch	θ	v	q
Normal	Z	Z	yawing	N	$X \longrightarrow Y$	yaw	ψ	w	r

FIG. 1

Part I—Theory

In the study of airplane stability it is necessary to establish conventions, both with respect to axes and symbols in order to set up the equations of motion. The system used will be that adopted as standard by the N. A. C. A., as indicated in Figure 1.

The following symbols are also defined:

W = gross weight
g = acceleration due to gravity
B = mass moment of inertia about Y
U = speed along flight path (wind axes)
Θ = equilibrium flight path angle
e = base of natural logarithms
λ = damping coefficient
T = time in seconds
C_1, C_2 etc. = constants

The airplane in flight has six degrees of freedom, namely, a displacement and a rotation along or about each of the three axes of reference, X, Y, and Z. For small displacement upon which stability theory is based, the longitudinal or symmetric motion which involves a displacement in X, a displacement in Z, and a rotation about Y, may be considered apart from the lateral or asymmetric motion which involves a displacement in Y, a rotation about X, and a rotation about Z. The fact that the longitudinal motion may be treated as independent from the lateral motion greatly simplifies the work. The axes of reference are chosen so as to further simplify the work as much as possible. The axes are assumed to be fixed in the airplane and to move with it. The forces and moments are referred to a set of reference axes having the same origin and momentarily fixed relative to the moving axes. Since the longitudinal motion may be considered as being confined to the plane of symmetry it is convenient to orientate the X axis along the direction of the relative wind in the equilibrium position, and this orientation shall be used for the study of the longitudinal motion. In a later discussion it may be shown that it is more convenient to employ a different orientation in the study of the lateral motion.

Longitudinal Motion

The longitudinal motion of the airplane in the plane of symmetry may be considered as involving linear displacement in the X direction, a linear displacement in the Z direction, and an angular displacement in pitch.

The velocities along X and Z are u and w respectively, and the displacement in pitch is Θ. These, with time, are the fundamental variables in the equations of motion. In the analysis of longitudinal stability one is concerned with the period and the damping of these relatively slow vibrations in X, Z, and Θ.

The equations of equilibrium for planar motion are:

$$\Sigma X = 0$$
$$\Sigma Z = 0$$
$$\Sigma M = 0$$

For the airplane in a gravitational field, moving with forces and moments referred to axes orientated parallel to and normal to the relative wind and neglecting the thrust moment, these equations may be written:

$$\frac{W}{g}\frac{du}{dt} = X + W\sin\theta$$

$$\frac{W}{g}\frac{dw}{dt} - Uq = Z - W\cos\theta$$

$$B\frac{dq}{dt} = M$$

Using the shortened stability notation where $Xu = \frac{\partial X}{\partial U}\frac{g}{W}$ and $Mu = \frac{\partial M}{\partial U}\frac{1}{B}$, etc., and omitting terms which are unimportant, the acceleration equations may be written:

$$\frac{du}{dt} = uXu + wXw + qXq + \theta g\cos\theta$$

$$\frac{dw}{dt} = uZu + wZw + qZq + \theta g\sin\theta + Uq$$

$$\frac{dq}{dt} = uMu + wMw + qMq$$

where Xu = the variation of X force (in terms of the mass) with velocity, u along X

and Mu = the variation of moment about Y (in terms of the mass moment of inertia, B) with velocity u along X

Mq = the variation of moment about Y (in terms of B) with angular velocity, q, about Y

Etc.

This is the classical form of the force and moment partial derivative with respect to velocity, which will be used in summarizing the general theory of longitudinal stability. Later it shall be shown that, in the solution of problems, it is advantageous to adopt a non-dimensional form for these quantities which results in a description of the motion which is numerically much more compact.

The substituting a function of the variable t,

let $u = C_1e^{\lambda T}$,
$w = C_2e^{\lambda T}$,
and $\theta = C_3e^{\lambda T}$.

If these values are substituted appropriately in their basic and differentiated forms, the equations of motion become:

$$C_1(\lambda - Xu) - C_2Xw - C_3(\lambda Xq + g\cos\theta) = 0,$$
$$-C_1Zu + C_2(\lambda - Zw) - C_3(\lambda Zq + g\sin\theta + U\lambda) = 0,$$
$$-C_1Mu - C_2Mw + C_3(\lambda^2 - \lambda Mq) = 0.$$

It is essential in the solution of these three simultaneous equations that their determinant = 0. This is represented in the following matrix:

$$K = \begin{vmatrix} (\lambda - Xu) & -Xw & -(\lambda Xq + g\cos\theta) \\ -Zu & (\lambda - Zw) & -(\lambda Zq + g\sin\theta + U\lambda) \\ -Mu & -Mw & +(\lambda^2 - \lambda Mq) \end{vmatrix} = 0$$

The expansion of the determinant results in a quartic which may be written in the form:

$$A\lambda^4 + B\lambda^3 + C\lambda^2 + D\lambda + E = 0$$

in which the coefficients, assuming that Xq and Zq are negligible, are: $A = 1$,

$B = (-Xu - Zw - Mq)$,
$C = (XuZw + XuMq + ZwMq - MuU - ZuXw)$,
$D = (-XuZwMq - MuXwU - Mu\,g\cos\theta - Mw\,g\sin\theta + XuMwU + ZuXwMq)$,
$E = (-ZuMw\,g\cos\theta - MuXw\,g\sin\theta + MuZw\,g\cos\theta + XuMw\,g\sin\theta)$,

and Routh's discriminant, $R = BCD - AD^2 - B^2E$.

The conditions of stability are satisfied if all of the coefficients, A, B, C, D, and E, and also Routh's discriminant, R, are positive, and the disturbances will decrease with time. However, if stability is to be rated quantitatively, the period and the damping of the oscillatory motion must be calculated. When E is negative the motion will not be oscillatory but will be divergent in character and in this case it is important to determine the time to double a given divergence. To accomplish this it is necessary to factor the quartic and Bairstow[3] has shown that the factors can be represented approximately by the two quadratics,

$$\left[\lambda^2 + \frac{B}{A}\lambda + \frac{C}{A}\right]\left[\lambda^2 + \left(\frac{DC - BE}{C^2}\right)\lambda + \frac{E}{C}\right] = 0$$

where the first factor refers to a heavily damped oscillation, in which the decay of the motion is so rapid that the pilot is not concerned with it; the second factor represents the longer and less rapidly damped motion or the "phugoid"[4] motion. The latter is the important one from the standpoint of control and passenger comfort. Solving the second quadratic in the usual manner, one writes,

$$\lambda = \frac{BE - DC}{2C^2} \pm \sqrt{\left(\frac{BE - CD}{2C^2}\right)^2 - \frac{E}{C}}$$

If the quantity under the radical is negative the roots will be complex, representing an oscillation which is damped if the real part of the root is negative and which increases with time if the real part is positive. When both roots are real, stability requires that they be negative. This represents a subsidence without oscillation. This condition with respect to the longitudinal motion is rarely met in practice. The period of

[3] L. Bairstow, B. M. Jones, and A. W. H. Thompson, *"Investigation Into the Stability of an Aeroplane, with an Examination Into the Conditions Necessary in Order That the Symmetric and Asymmetric Oscillations Can Be Considered Independently,"* R. and M. 77, Brit Ad. Comm. Aero., Tech. Rept., 1912–1913.

[4] After F. W. Lanchester, *Aerodonetics*, Constable & Co., London, 1908.

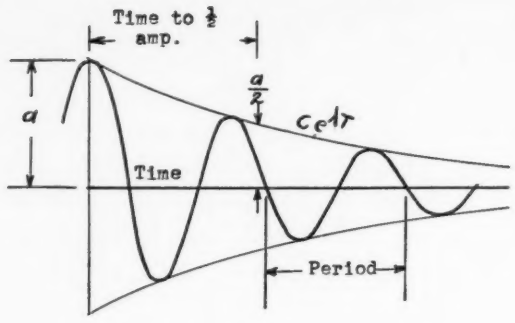


FIG. 2

the long oscillation is $P = \dfrac{2\pi}{\sqrt{\dfrac{E}{C} - \left(\dfrac{BE - CD}{2C^2}\right)^2}}$.

or to a very close approximation:

$$P = \frac{2\pi}{\sqrt{\dfrac{E}{C}}}.$$

and the time to damp a disturbance to ½ amplitude is expressed as:

$$T = \frac{-ln2}{\dfrac{BE - CD}{2C^2}}.$$

If the motion is unstable, this gives the time to double the amplitude. Fig. 2 is a plot of disturbance *vs.* time for the case of the damped oscillation.

The envelope of the oscillation is described by $a = Ce^{\lambda T}$ where λ is negative for stable motion.

In order that the airplane have a satisfactory natural motion, it is essential that the period of the phugoid oscillation be long with respect to lag in pilot reaction[5] (this will always be the case for the longitudinal motion), and that the disturbance be rapidly damped. In this connection possibly a better index of stability than either the period or the damping time alone, is their quotient, T/P, or the number of oscillations to halve a given disturbance.

THE DERIVATIVES

The substitution of a non-dimensional set of stability derivatives (due to Glauert)[6] for the classical set leads to the desirable result of confining the numerical values of the derivatives to a small range and simplifies the understanding of the effect upon stability of such variables as size, wing loading, density, etc. In view of these facts, and because this notation is used by the British, whose investigations and writings in this subject are the most extensive existing it is advantageous to adopt it.

The classical derivatives Xu, Xq, Mu, Mq, etc. (in terms of the mass or the mass moment of inertia) are replaced by the non-dimensional forms, x_u, x_q, m_u, m_q, etc., in which the equations connecting the two systems are:

$$Xu = \frac{x_u}{\tau}$$

$$Xq = \frac{x_q \cdot L}{\tau},$$

$$Mu = \frac{m_u}{\tau L \cdot \eta},$$

$$Mq = \frac{m_q}{\tau \cdot \eta}.$$

η is the mass distribution factor and is defined:

$$\eta = \frac{B}{\dfrac{W}{g} L}$$

where the unit of length, L, is the distance in feet from the C. G. to the center of pressure of the tail, and the unit of time is τ seconds.

$$\tau = \frac{m}{\rho/2\, S\, U},$$

in which m is the mass of the airplane.

The unit of velocity now becomes $\frac{L}{\tau}$ or $\frac{U}{\mu}$ ft. per second, where $\mu = \dfrac{m}{\rho/2\, S\, L}$,

The parameter, μ, is a criterion of similarity with respect to variation in the relative inertia of the airplane and the air through which it flies.

The effects of size, wing loading, and altitude, enter into the equations in the value of μ and may thus be treated under a single variable.

The other symbols not already defined are:

S = wing area (sq. ft.),
ρ = mass density of air (slugs),
U = velocity of steady flight (ft. per sec.).

Expressing the weight in terms of the lift coefficient, C_L, and allowing $\cos \Theta = 1$ and $\sin \Theta = 0$, the non-dimensional stability matrix becomes:

$$K_1 = \begin{vmatrix} (\lambda - x_u) & -x_w & -\mu C_L \\ -z_u & (\lambda - z_w) & -\mu(C_L\theta - \lambda) \\ -m_u & -m_w & \lambda^2 - \lambda m_q \end{vmatrix} = 0,$$

and the non-dimensional quartic is

$$A_1\lambda^4 + B_1\lambda^3 + C_1\lambda^2 + D_1\lambda + E_1 = 0,$$

where:

$A_1 = 1$
$B_1 = -(z_w + m_q + x_u)$
$C_1 = m_q(z_w + x_u) - \mu m_w + x_u z_w - x_w z_u$
$D_1 = m_q(x_w z_u - x_u z_w) + \mu m_w(x_u - C_L\theta) - \mu m_u(x_w + C_L)$
$E_1 = -C_L \mu m_w(z_u - x_u\theta) - C_L \mu m_u(x_w\theta - z_w)$.

[5] H. M. Garner, *Lateral Stability With Special Reference to Controlled Motion*, R. and M. 1077, Br. Aero. Res. Comm., 1926.

[6] H. Glauert, *A Non-Dimensional Form of the Stability Equations of an Aeroplane*, R. and M. 1093, Br. Aero. Res. Comm., 1927.

C_L is the absolute lift coefficient for equilibrium in flight.

The angle Θ for wind orientated axes is expressed in radians and is the flight path angle relative to the horizon in equilibrium flight. Θ is positive in climb, zero in level flight, and negative in a glide. It should be noted that the quantity μ is always associated with m_w and m_u. For gliding flight the terms in D_1 and E_1 containing m_u vanish, since, when elevators are fixed, m_u has a finite value only in the power-on condition.

The period, p, and the time to damp to ½ amplitude t, expressed in τ units are:

$$p = \frac{2\pi}{\sqrt{\frac{E_1}{C_1} - \left(\frac{B_1E_1 - C_1D_1}{2C_1^2}\right)^2}}$$

$$t = \frac{-\ln 2}{\frac{B_1E_1 - C_1D_1}{2C_1^2}},$$

from which the actual period and time to damp in seconds is obtained from the relations:

$P = (p \times \tau)$ seconds,

$T = (t \times \tau)$ seconds.

In the foregoing, the mathematical reasoning leading to these expressions for period and damping time has been sketched briefly. However, insofar as the designer is concerned, he need only evaluate the non-dimensional derivates using simple formulae based upon the geometry and mass distribution of the airplane, insert these in the expressions for the coefficients which are in turn substituted in the period and damping equations, and arrive at a description of the stability, using only very simple mathematics.

Part II. Stability Estimation

As an example, the stability of a representative modern airplane will be calculated for the powered flight condition and described in terms of the period and damping times. As each derivative is discussed, the value appropriate for this airplane will be computed. The type chosen is a typical twin-motored transport monoplane, assumed in the attitude for climb at full throttle at altitude, since this would be a critical case.

In evaluating the derivatives, no attempt will be made to do more than to offer expressions which are generally accepted as satisfactorily describing the contributions made by these terms. More detailed treatment may be found in the available writings in this field, particularly in Aerodynamic Theory, Vol. V, Division N, *Dynamics of the Airplane*, by B. M. Jones.[7] The derivatives are valid for the range of angles of attack over which the lift curve may be assumed linear. It should be mentioned that certain of the derivatives given here would require modification in the case of a flying boat where the thrust line is at an appreciable distance from the center of gravity.

It will be convenient to list the necessary design information with the appropriate algebraic signs. The more familiar symbols will be defined briefly here; the other quantities will be explained as they occur.

Basic Data

Calculation for climb at 197 ft. per second (135 m.p.h.) full throttle, at 7000 feet.

Symbols	*Designation*	*Data Used*
U	Flight path equilibrium velocity	— 197 ft./sec.
U_1	Level flight velocity at prescribed throttle setting	— 320 ft./sec. approx.
θ	Flight path angle relative to horizon	+ .080 radian.
ρ	Mass density of air at 7000 feet	.001928 slugs/ft.^{3}
W	Gross weight of airplane	18,560 lbs.
m	Mass of the airplane	576 slugs
S	Wing area	939 sq. ft.
W/S	Wing loading	19.77 lbs./ft.^{2}
C_L	Lift coefficient at velocity U	— .530
C_{L1}	Lift coefficient at velocity U_1	— .214
C_D	Drag coefficient appropriate for velocity U	— .0381
C_{D1}	Drag coefficient appropriate for velocity U_1	— .0264
R	Aspect ratio of wing b^2/S	7.7
$\left(\frac{dC_L}{d\alpha}\right)_{R=7.7}$	Slope of lift curve at aspect ratio R	4.62 per radian.
$\left(\frac{dC_D}{d\alpha}\right)_{R=7.7}$	Slope of drag curve at aspect ratio R	2.03 per radian.
L	Distance from C. G. to C. P. of horiz. tail	— 31.8 ft.
b	Span of wing	85.0 ft.
C	Mean wing chord S/b	11.05 ft.
f	Distance of C. G. above wing chord	2.8 ft.
S'	Horizontal tail area	150.0 sq. ft.
b'	Span of horizontal tail	26 ft.
S'/S	Horiz. tail as a percentage of wing area	.16
R'	Aspect ratio of horiz. tail	4.5
$(dC_L/d\alpha)'_{R=4.5}$	Slope of lift curve of tail	3.99 per radian
e	Tail efficiency factor	.80
h	Height of airplane in flying position	15 ft.
OL	Overall length of airplane	62 ft.
η	Mass distribution factor	0.145

[7] Also, S. B. Gates, *A Survey of Longitudinal Stability. Below the Stall With an Abstract for Designers' Use.* Br. Aero. Res. Comm., R. and M. 1118, 1927.

D	Propeller diameter	12 ft.
Q	Fraction of horiz. tail in the slip-stream	.75
N	Number of propellers laterally disposed	2

It is necessary to determine the horizontal distance from the aerodynamic center to the center of gravity. Call this distance, expressed in terms of the mean chord, H. For modern tapered wings having sweepback and twist, the location of the aerodynamic center must be determined by calculation. N. A. C. A. Technical Note No. 483 presents a convenient method of doing this. The expression for H may then be written:

$$\left[\frac{a}{C}-\left(.25\,\frac{C_e}{C}+\frac{d}{C}\right)\right]=H\,.$$

where:

a = a distance of C. G. from leading edge along center chord,

C_e = center chord (in plane of symmetry),

d = distance from the ¼ C_e point to the axis through the aerodynamic center, (A.C.).

$C = s/b$ = mean chord.

(Charts for determining d are included in T. N. 483.) For a straight rectangular wing this reduces to $\left(\frac{a}{c}-.25\right)=H$. For the airplane under consideration let: $H = +.03$ (Positive if C. G. is aft of A. C.)

For powered flight the value of the pitching moment coefficient about the aerodynamic center is needed. This also may be evaluated for the tapered wing by use of the formulae and charts of T. N. 483. For the rectangular wing this, of course, is simply the moment about the quarter chord.

A representative value for our airplane is:

$C_{mac} = -.03$,

and the coefficient of wing moment about the C. G. may be approximated by:

$$\begin{aligned} C_{mwcg} &= C_{mac} - H(C_L) \\ &= -.03 - (.03)\ (-.530) \\ &= -.014 \qquad \text{for our analysis.} \end{aligned}$$

The moment of inertia, B, may be determined by summation of the products of the unit weights and the distances squared, as explained in N. A. C. A., T. N. 575, or it may be estimated using average coefficients. The latter method is much the easier and should be sufficiently accurate for our purposes. Then:[8]

$$B = C_b\,(h^2 + (OL)^2)\,\frac{W}{g}$$

for which

C_b = a coefficient of distribution.

h = the height of the airplane when level.

OL = the overall length

and $\eta = \dfrac{C_b\,(h^2 + (OL)^2)}{L^2}$.

C_b has an average value of 0.036.

Calculating η:

$$\eta = \frac{0.036\ ((15)^2 + (62)^2)}{(31.8)^2},$$

$$\eta = 0.145.$$

The Derivatives

x_u

$x_u = 2C_D$ ..... for glide

$x_u = 2C_D + .62\left(\frac{C_{D_1}}{C_{L_1}}\right)\sqrt{C_{L_1}C_L}$ ..... power on

then $x_u = 2(-.0381) + .62\left(\frac{-.0264}{-.214}\right)\sqrt{(-.214)(-.530)}$

$= -.102.$

$C_D = \dfrac{D}{Sq}$ = the overall drag coefficient based upon wind tunnel test or calculation.

$C_L = \dfrac{L}{Sq}$ = the overall life coefficient.

These terms with the subscript, 1, are relative to the *level flight* condition for the specified throttle setting at the altitude under consideration. Both terms in the expression for x_u are always negative.

x_w

$x_w = \left(\dfrac{dC_D}{d\alpha}\right)_R - C_L$ for power on and off.

The part of the drag coefficient which is variant with α is the induced drag coefficient where

$$C_{Di} = \frac{C_L^2}{\pi R},$$

from which

$$\left(\frac{dC_D}{d\alpha}\right)_R = \frac{2C_L}{\pi R}\left(\frac{dC_L}{d\alpha}\right)_R,$$

where $\left(\dfrac{dC_L}{d\alpha}\right)$, for $R = 7.7$, may be expressed as

$$\left(\frac{dC_L}{d\alpha}\right)_{7.7} = \frac{\left(\dfrac{dC_L}{d\alpha}\right)_\infty}{1 + \dfrac{\left(\dfrac{dC_L}{d\alpha}\right)_\infty}{\pi R}}, \text{ where } R = \frac{b^2}{S}.$$

$\left(\dfrac{dC_L}{d\alpha}\right)_\infty$, for infinite aspect ratio, may be taken as 5.7 per radian.

Then $\left(\dfrac{dC_L}{d\alpha}\right)_{7.7} = \dfrac{5.7}{1 + \dfrac{5.7}{3.14 \times 7.6}} = 4.62$ per radian,

which for the conventions established becomes —4.62.

[8] M. P. Miller and H. A. Soule, *Moments of Inertia of Several Airplanes*, N.A.C.A. Tech. Note 375, 1931.

Then,

$$\left(\frac{dC_D}{d\alpha}\right)_{i,j} = \frac{2\,(-.530)}{3.14 \times 7.7}(-4.62) = .203,$$

which also for these conventions becomes —.203.
Then: $x_w = -.203 - (-.530) = +.327$

z_u

$z_u = 2C_L$ for power on and off; or for this case: $z_u = -1.060$.

z_w

$z_w = \left(\frac{dC_L}{d\alpha}\right)_R$ for power on and off, and for this case:

$$z_w = \left(\frac{dC_L}{d\alpha}\right)_{i,j} = -4.62$$

m_u

$m_u = 0$, power off.

$$m_u = \frac{C_{mwcg}}{\eta}\frac{C}{L}\frac{Q}{1+Q\,(R-1)}\left(U\frac{dR}{dU}\right), \text{ power on,}$$

where $C_{mwcg} = \frac{M_{wcg}}{CSq}$ = Coefficient of wing moment about the C. G.

η = the mass distribution factor, previously calculated.

$C = \frac{S}{b}$ (ft.) = mean chord.

L = distance from C. G. to $\frac{1}{4}$ chord of horizontal tail (ft.)

Q = fractional part of tail affected by slip stream; (this term must be estimated.)

$$(R-1) = -\frac{4S}{N\pi D^2}C_L\left(\frac{C_{D_1}}{C_{L_1}}\right)\left(1.62 - .62\sqrt{\frac{C_{L_1}}{C_L}}\right).$$

C_{L1} and C_{D1} refer to maximum level flight condition at the prescribed throttle setting.

N = number of propellers laterally disposed.

D = propeller diameter (ft.)

$$\left(U\frac{dR}{dU}\right) = -\frac{4S}{N\pi D^2}C_L\left(\frac{C_{D_1}}{C_{L1}}\right)\left(.62\sqrt{\frac{C_{L1}}{C_L}} - .324\right).$$

The above takes advantage of a relation between the velocity and the thrust in terms of the thrust at maximum efficiency and is due to Glauert.

For the airplane under consideration

$$(R-1) = -\frac{4(939)}{2\pi(144)}(-.530)\left(\frac{-.0264}{-.214}\right)\left(1.62-.62\sqrt{\frac{(-.214)}{(-.530)}}\right) = .333$$

$$\text{and } U\frac{dR}{dU} = -\frac{4(939)}{2\pi(144)}(-.530)\left(\frac{-.0264}{-.214}\right)\left(.62\sqrt{\frac{(-.214)}{(-.530)}} - .324\right) = -.774$$

$$\text{then } m_u = \frac{(-.014)}{.145}\frac{11.05}{(-31.8)}\left(\frac{.75}{1+.75(.333)}\right)(-.774) = -.0156$$

This term appears only in the power-on condition and its effect is to increase the damping if the wing moment coefficient is negative. The percentage of total tail area in the slip stream is difficult to estimate. A suggested method is to consider it as 0.8 of the area enclosed by the projection of the propeller disc aft. This roughly allows for slip stream contraction and reduction in average intensity.

m_w

for power on and off:

$$m_w = \frac{1}{\eta}\left[\left(\frac{dC_L}{d\alpha}\right)_R\frac{C}{L}H - \left(\frac{dC_t}{d\alpha}\right)\frac{C}{L}\frac{f}{C} + e\left(\frac{dC_L}{d}\right)'_{R'}\frac{S'}{S}\left(1-\frac{d\epsilon}{d\alpha}\right)\right],$$

in which the quantities not heretofore explained are:

$\left(\frac{dC_t}{d\alpha}\right)$ = variation of tangential force coefficient with angle of attack

f = distance from the C. G. to the wing chord. This term is positive for the low wing position and negative for the high wing type.

e = tail efficiency and varies with tail position and body size. $e = .80$ is a fair average value.

$\left(\frac{dC_L}{d\alpha}\right)'_{R'}$ = variation of life coefficient *vs.* α for the tail at the tail aspect ratio, R'.

$\frac{S'}{S}$ = horizontal tail area expressed as a percentage of wing area.

$\frac{d\epsilon}{d\alpha}$ = variation of downwash angle with α

$\frac{dC_t}{d\alpha}$ may be evaluated closely by: $\frac{dC_t}{d\alpha} = \left(\frac{dC_D}{d\alpha}\right)_R - C_L$,

and $\left(\frac{dC_L}{d\alpha}\right)'_{R'} = \frac{5.7}{1+\frac{5.7}{\pi R'}}$.

This term is negative for the conventions which have been established.

Also:

$$\frac{d\epsilon}{d\alpha} = -\frac{.5}{R}\left(\frac{dC_L}{d\alpha}\right)_R.$$

where R = wing aspect ratio and $\left(\frac{dC_L}{d\alpha}\right)_R$ carries a negative sign. For our airplane:

$$\frac{dC_t}{d\alpha} = -.203 - (-.530) = +.327$$

Note that this is identical with x_w

$$\text{and } \left(\frac{dC_L}{d\alpha}\right)'_{R'} = \frac{5.7}{1+\frac{5.7}{3.14\times 4.5}} = 3.99,$$

which becomes in this system,

$$\left(\frac{dC_L}{d\alpha}\right)'_{R'} = -.399.$$

Also $\frac{d\epsilon}{d\alpha} = -\frac{.5}{7.7}\ (-4.62) = .30$

Then:

$$m_w = \frac{1}{.145}\left[(-4.62)\left(\frac{11.05}{-31.8}\right)(.03) - (.327)\left(\frac{11.05}{-31.8}\right)\left(\frac{2.8}{11.05}\right) + .80\ (-3.99)\left(\frac{150}{939}\right)(1-.30)\right]$$

$$= \frac{1}{.145}(.0482 + .0288 - .357) = -1.93$$

The effects of power upon m_w approximately balance each other so that the same expression is satisfactory for both power on and off.

m_q

$$m_q = \frac{1}{\eta}\frac{5}{4}\ e\left(\frac{dC_L}{d\alpha}\right)'_{R'}\frac{S'}{S}\ \text{, power off.}$$

$$m_q = \frac{1}{\eta}\frac{5}{4}\ e\left(\frac{dC_L}{d\alpha}\right)'_{R'}\frac{S'}{S}\left[1 + Q\ (R-1)\right]\ \text{, power on.}$$

Substituting in this expression:

$$m_q = \frac{1}{.145}\frac{5}{4}\ (.80)\ (-3.99)\left(\frac{150}{939}\right)\left[1 + .75\ (.333)\right]$$

$$= -5.50$$

Calculating the non-dimensional time factor, τ, and the parameter, μ:

$$\tau = -\frac{W}{g\frac{\rho}{2}SU}$$

Then $\tau = -\dfrac{18{,}560}{32.2\left(\frac{.001928}{2}\right)(939)\ (-197)}$ for 7000 ft., or

$$\tau = 3.23\ ,$$

and $\mu = \dfrac{W}{g\frac{\rho}{2}SL} = -\dfrac{18.560}{32.2\left(\frac{.001928}{2}\right)(939)\ (-31.8)} = 20.0$

The path angle, Θ, for the power off condition is:

$$\theta = -\frac{C_D}{C_L}$$

and with power:

$$\theta = \left(\frac{C_{D_1}}{C_{L_1}}\right)\left(1.62 - .62\sqrt{\frac{C_{L_1}}{C_L}}\right) - \frac{C_D}{C_L}$$

Then $\theta = \left(\dfrac{-.0264}{-.214}\right)\left(1.62 - .62\sqrt{\dfrac{(-.214)}{(-.530)}}\right) - \left(\dfrac{-.0381}{-.530}\right) = .152 - .072 = +.080$ radians.

The data needed for evaluation of the coefficients may be summarized:

x_u	=	− .102	θ	=	+ .080
x_w	=	+ .327	m_u	=	− .0156
z_u	=	− 1.060	m_w	=	− 1.93
z_w	=	− 4.62	m_q	=	− 5.50
μ	=	+ 20.0	μm_u	=	− .312
C_L	=	− .530	μm_w	=	− 38.6

The coefficients of the non-dimensional quartic become:

$A_1 = 1$

$B_1 = -(z_w + m_q + x_u) = +10.22$

$C_1 = m_q(z_w + x_u) - \mu m_w + x_u z_w - x_w z_u = +66.53$

$D_1 = m_q\ (x_w z_u - x_u z_w) + \mu m_w(x_u - C_L\theta) - \mu m_u\ (x_w + C_L) = +6.76$

$E_1 = -C_L\mu m_w\ (z_u - x_u\Theta) - C_L\mu m_u\ (x_w\Theta - z_u) = +20.68$

It is seen that the coefficients A_1, B_1, C_1, D_1, and E_1 are all positive and the condition for stability is that R, also must be positive.

$$R = B_1C_1D_1 - D_1^2 - B_1^2\ E_1 = +4000,$$

indicating that the airplane in question is stable.

It is not enough, however, to know merely that stability exists but it is essential to determine the period and the damping of the motion for comparison with data for other airplanes known to be satisfactory or otherwise.

The non-dimensional period of the phugoid motion is:

$$p = \frac{2\pi}{\sqrt{\frac{E_1}{C_1} - \left(\frac{BE - CD}{2C^2}\right)^2}}$$

Since the second term under the radical is very small as compared with $\frac{E_1}{C_1}$ the period is expressed approximately by:

$$p = \frac{2\pi}{\sqrt{\frac{E_1}{C_1}}} = \frac{2(3.14)}{\sqrt{\frac{20.68}{66.53}}} = 11.15\ \tau\ \text{units.}$$

Since for this case, it has been calculated that $\tau = 3.23$, the actual period in seconds is:

$$P = p\tau = 11.15 \times 3.23 = 36\ \text{seconds,}$$

and the time to damp the disturbance to $\frac{1}{2}$ amplitude is:

$$t = \frac{-ln\ 2}{\frac{B_1E_1 - C_1D_1}{2C_1^2}} = 25.8\ \tau\ \text{units.}$$

The damping time in seconds is $T = t\tau = 83.4$ seconds.

The disturbed motion will damp to $\frac{1}{2}$ amplitude in T/P oscillations, which in this case is 2.32 oscillations.

In the longitudinal motion, the minimum value of the period of the important oscillation is always so long that no problem exists relative to keeping it long with respect to pilot lag, as may be the case for lateral motion.

Although it is agreed that damping should be rapid, there exists no generally accepted criterion as to what the period of the longitudinal oscillation should be. At the present time when so much thought is being given to passenger comfort, it would seem to be important to determine, experimentally, that period which is least conducive to air-sickness and to incorporate it in the design of the airplane. If the desired period is found to be the minimum value possible, as some believe it is, designers should make serious attempt to provide this period in the airplane.

The airplane for which the longitudinal motion has been estimated has a period (36 seconds) which may, by suitable adjustment of the derivatives, be reduced by approximately 10 seconds. The derivatives which come under the designer's control are m_w and m_q. It is also of interest to note that the period varies appreciably with the lift coefficient; the longer periods being associated with higher speeds.

The damping, expressed as the number of oscillations to halve the amplitude (in this case, 2.30 oscillations), offers room for improvement and here again appropriate adjustment of the derivatives will improve the damping.

It is not so easy in the case of the damping to see just what derivatives, subject to change by reasonable design variations, are important. However, damping is most directly improved by increasing the negative value of x_u, but since x_u is approximately proportional to the drag coefficient, this procedure is opposed to aerodynamic efficiency and unavailable to the designer. It is, therefore, necessary to obtain the desired damping by adjustment of design features influencing m_q, x_w, z_w and to some extent, m_w. A little practice in the use of the method will give an insight into the effect on the stability, of various design changes.

The important effects of power are to make Θ more positive, to increase the negative value of m_q and to introduce m_u. A more positive Θ decreases the damping, (increases the number of oscillations to halve the amplitude) but has little effect upon the period, while increasing m_q has the effect of improving the damping. Under normal design conditions the effect of m_u is to shorten the period and increase the damping at high speeds. This reduction in damping at low speed, together with the further reduction in damping due to a more positive flight path angle, probably represents the power-on contributions which are most detrimental to stability and indicate the lower part of the speed range as critical.

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Dinner to Dr. George W. Lewis

On the Occasion of the Presentation of the Daniel Guggenheim Medal

OVER three hundred and fifty members of the Institute and guests attended a banquet given in honor of Dr. George W. Lewis, Director of Research of the National Advisory Committee for Aeronautics, at the Hotel Biltmore, New York, on Friday, December 4, 1936.

Dr. Lewis was presented with the Daniel Guggenheim Medal *"For outstanding success in the direction of aeronautical research, and for the development of original equipment and methods."*

The Daniel Guggenheim Medal is presented annually for notable achievements in the advancement of aeronautics. It was established in 1928 in commemoration of the support given by Daniel Guggenheim to the advancement of aeronautics through donations for the support of schools of aeronautics and for the encouragement of civil aviation. Other recipients of the award have been Orville Wright, Ludwig Prandtl, F. W. Lanchester, Juan de la Cierva, J. C. Hunsaker, W. E. Boeing and William F. Durand.

This year, for the first time, the Institute of the Aeronautical Sciences became one of the participating societies which select the Medal Board and the Council of the Institute decided that a special program should be arranged to honor Dr. Lewis, who is also Vice President of the Institute. During the afternoon a special technical session was held, an account of which appears elsewhere in this issue.

Glenn L. Martin, President of the Institute, introduced the toastmaster, Hon. Harry F. Guggenheim. He expressed the appreciation of the Institute to James H. Herron, President of the American Society of Mechanical Engineers, and Ralph R. Teetor, President of the Society of Automotive Engineers, for the courtesy of these organizations in making it possible for the Institute to become a joint sponsor with them in the annual presentation of the medal.

Owing to the lengthy list of speakers who had come to pay a tribute to Dr. Lewis, Mr. Guggenheim limited his introduction to a few words in presenting each of the speakers. He said that so many telegrams of felicitation had been received that he could not read them all but he would read three.

He first read a telegram from Dr. Joseph S. Ames, Chairman of the National Advisory Committee for Aeronautics.

"Please convey to Dr. Lewis this message. Please accept my hearty congratulations on the honor which is being shown you today. It is well merited in every sense, and I congratulate you, the Institute of the Aeronautical Sciences and the Guggenheim Medal Committee on this most happy event."

The following telegram was received from Orville Wright.

"I had hoped to be at the dinner this evening to show by my presence the high esteem in which I hold the contributions of Dr. Lewis toward the advancement of aeronautics. But that has not been possible. I ask you, therefore, to extend to Dr. Lewis my heartiest congratulations on his recognition by others of the value of his work. I am pleased to have him join our small group who are the proud possessors of the Guggenheim Medal. Also, please extend to Dr. Lewis an appreciation of my own affectionate good wishes."

The third telegram read was from H. E. Wimperis, President of the Royal Aeronautical Society.

"As President of the Royal Aeronautical Society, I send on behalf of the Council and members cordial felicitations of the signal honor of the award to you of the Guggenheim Medal. As one who has the pleasure of knowing you personally, and who highly esteems your excellent work for aeronautical research, I add my own personal congratulations to these official ones."

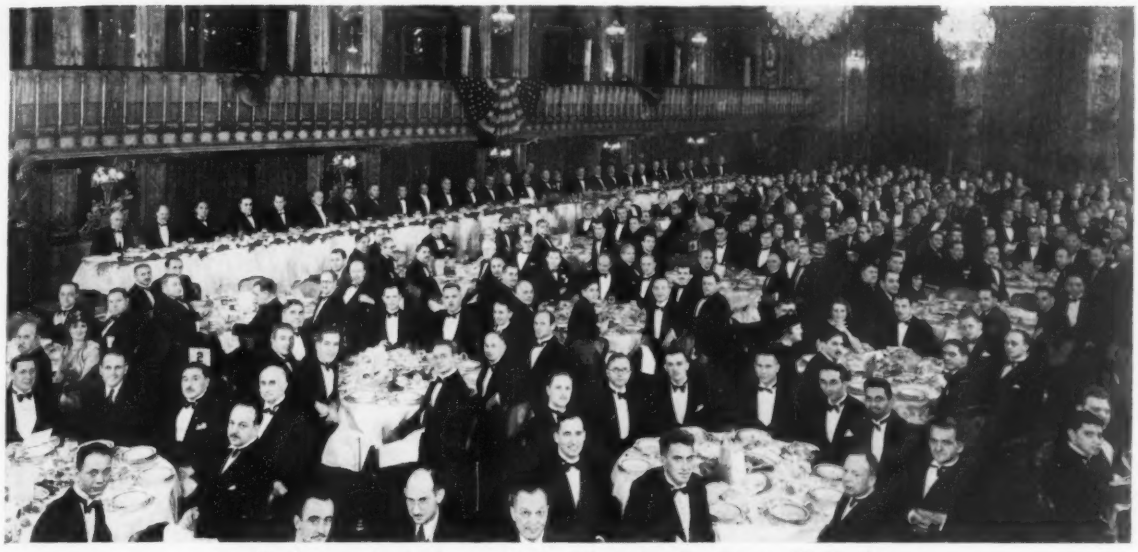
Major E. E. Aldrin, President of the Daniel Guggenheim Medal Fund, the first speaker, gave a history of the Daniel Guggenheim Medal since its establishment in 1928. Brief abstracts from the talks of other speakers follow:

Major General O. Westover, Chief of the Air Corps, U. S. Army, spoke for the War Department.

"When we consider the marked position of superiority and achievement which characterizes our aeronautical industry today, the progress made in the field of that development, the progress made in our military and naval aircraft, we realize that it is not alone due to the inventive genius which we consider characteristic of our fellow American, nor do we consider that it is entirely due to the fact that air transportation was in great demand in this country due to our enormous distances and the desire to travel over them quickly. Nor do I consider it due so much to the pioneering done by the Army and the Navy in the early days before the war, during the war and after the war in developing aeronautics. But I consider it is due in large measure and probably the greatest measure to the result of the work of that group of engineers and scientists whose headquarters is located at the Langley Memorial Laboratory, and whose efforts in the field of fundamental scientific research in aeronautical problems have resulted in the marvelous advance made in this country in aeronautics.

"I consider that since they bear the glory, that we are indeed proud to be here tonight to pay tribute to the man whose leadership has directed that work, a man whose farsighted vision has pointed the way in research, and who has been farsighted enough to develop those peculiar pieces of apparatus so essential to keeping us in the forefront of fundamental research throughout the world.

"I also consider that this tribute is merited by that man and his leadership because in addition to being a leader in his own field, he has had that remarkable personal tact of coordinating so many other federal, civil and commercial agencies. Through that ability of his, he has been outstanding in bringing to a



Members of the Institute and Guests honoring Dr. George W. Lewis

focus in this country the dependence upon the National Advisory Committee for Aeronautics as the one agency charged with this important mission of fundamental research and development."

Rear Admiral A. B. Cook, Chief of the Bureau of Aeronautics, U. S. Navy, spoke for the Navy Department.

"Under Dr. Lewis' direction the N.A.C.A. Laboratory at Langley Field has grown steadily and systematically from a single administration building and one wind tunnel to become the most efficient aeronautical research organization in the world. The brilliant results that have been accomplished are too well known to require enumeration before such a group as is gathered here tonight; suffice it to say that all modern airplane design is based almost entirely on N.A.C.A. research data.

"No less remarkable than the material growth of the Laboratory is the outstanding group of scientists that Dr. Lewis has built up to form its technical staff. It is, in itself, a sterling tribute to his personality and ability that he is able to command the sincere respect and genuine loyalty of each and every member of his organization, to an extent rarely achieved in scientific work where "temperament" is frequently a cultivated trait.

"For many years the Navy Department has leaned heavily on Dr. Lewis and his organization in all matters pertaining to aeronautical research. The relations have been most cordial and beneficial. The steady improvement in the performance of Naval aircraft could not have been accomplished without the whole-hearted assistance of Dr. Lewis and his associates."

Eugene L. Vidal, Director of Air Commerce, Department of Commerce, said:

"As a representative of the Bureau of Air Commerce, which enjoys such splendid relations with the N.A.C.A., I feel that I am fully qualified to testify that Dr. Lewis has the confidence, respect and admiration of everyone in our organization, and we are grateful for the fact that fortune has placed him in such an important position.

"We feel we can turn, whenever we need help, to Dr. Lewis, and whenever we do we get it. I could recount many instances when he and his group have given inestimable service to us. In addition to his research activities, Dr. Lewis serves on practically every type of aviation committee, whether federal or civil in organization."

Hon. W. R. Gregg, Chief of the U. S. Weather Bureau, spoke for the Weather Bureau.

"Dr. Lewis joined the staff of the N.A.C.A. on November 6, 1919. Six months later the Weather Bureau received its first letter from him. Its subject was the "Standard Atmosphere." There followed soon the formation of a sub-committee and, later, the adoption of that sub-committee's report and recommendation. The use of a "Standard Atmosphere," more or less arbitrary though it be, has been and is a prerequisite in the attack on many aerodynamic problems.

"There was thus established a relationship of close and cordial cooperation which has continued through the years and which has expressed itself in the work done jointly as members of various committees and sub-committees."

Dr. Lyman J. Briggs, Director of the National Bureau of Standards, said:

"It is interesting to reflect at times as to what brings about the success of some particular institution, and tonight the institution that we are considering is the National Advisory Committee for Aeronautics.

"That is an independent agency, as we say in government circles, and yet it undoubtedly has the confidence and the enthusiastic support of all of the agencies in the government that are in any way associated with aeronautics.

"What brings this about? I think that in this case, at least, it is first a question of disinterested service, and a desire to secure effective cooperation among these various agencies so that there is no useless duplication in order that the programs are projected along well defined and constructive lines, and also in the background with the hope that along with the practical part there can be some fundamental developments carried on.

"I think that has been an objective of the National Advisory Committee for Aeronautics, and I think that these objectives have been made possible because Dr. Lewis believed in them and worked for them. I know that the Committee has not hesitated to have work done outside of its own laboratories when it thought there was an opportunity in some other place to carry on that work satisfactorily, in order that the program as a whole might be carried on as rapidly as possible."

Dr. C. G. Abbott, Secretary of the Smithsonian Institution, said, in part:

"For many years Dr. Wolcott was Chairman of the N.A.C.A. I am but a small successor of these giants. I have sat long enough upon the Committee to appreciate very fully and admire the excellent work which the Committee has carried on under the leadership of Dr. Ames and Dr. Lewis these many years.

"It was, therefore, a very great pleasure to me to have had the opportunity of recommending the award of the Langley Medal to Dr. Ames, and now, it is an equal pleasure to be associated with this fine tribute and honor which is being paid to my dear friend, Dr. Lewis.

"He has, for many years, been associated with Dr. Ames in the guidance of the affairs of the National Advisory Committee for Aeronautics, and under him, you all know how great has been the development and how great the debt of aviation the world owes to the National Advisory Committee for Aeronautics."

In introducing the representatives of England, France, Germany and Italy, Mr. Guggenheim stated that the precedence of the speakers had been arranged alphabetically. He requested them to convey the thanks of the Institute to their respective governments for the sending of the films and also for the courtesy shown to the Secretary of the Institute during his recent trip to Europe.

Group Captain T. E. B. Howe, Air Attaché of the British Embassy, said:

"As the British representative, I wish to express gratitude for the liberal exchange of technical information from the National Advisory Committee for Aeronautics, which is so much appreciated by the British Air Ministry and the Royal Aeronautical Society, and the other scientific bodies in my country.

"Everywhere I go, I find evidence of the liaison between scientific research and the aircraft industry, and I wish to congratulate the scientists and designers and engineers of this country in having such an able and energetic individual as Dr. Lewis to coordinate their efforts and interests in progress."

Colonel N. Champsaur, Air Attaché of the French Embassy, said, in part:

"It is a privilege for me to be able to congratulate Dr. Lewis in the name of my Ministry and in my own name upon the high distinction which has been bestowed upon him for his merits. Need I add that it is only an official recognition of the esteem in which he is held by all of us?

"Indeed, the researches achieved by the laboratories of the N.A.C.A. are known throughout the world and have been the basis of most of the stupendous progress realized in the field of aeronautics. But what is also an object of admiration which is highly deserving of our most grateful thanks, is the liberal way in which those works are released for the greatest benefit of all technical organizations in every country.

"As a conclusion, may I stress that Dr. Lewis is not only receiving the award due to his efficient efforts but his name is also justly linked to the name of Mr. Guggenheim, generous benefactor of aviation, and to the names of the distinguished men who have obtained in the past years this much esteemed Guggenheim Medal."

Dr.-Ing. F. Seewald, Director of the Deutsche Versuchsanstalt für Luftfahrt, of Berlin-Adlershof, Germany, spoke as a representative of the D.V.L.

"It gives me great pleasure to be able to be here tonight as a representative of the German Research Institute and to greet those who have been instrumental in bringing about such wonderful progress in American aeronautics. I consider it a great honor to express to you the admiration and the esteem which we in Germany have for American aviation, and for the men who have brought its technical progress to such a high level that the scientists and aeronautical engineers of the entire world admire it.

"It seems to me this success is largely due on the one hand to the ingenuity with which practical problems have been solved in this country and on the other hand, to persistent scientific research work to enlarge knowledge about the fundamental problems of human flight.

"I do not think that there is one problem which is not fundamentally treated in an American report. The research work of the National Advisory Committee under the direction of Dr. Lewis has furnished fundamental knowledge which is responsible for the most remarkable progress in increasing the efficiency of aircraft.

"I am glad to say that we in Germany have greatly profited by this work, and that the technical progress in Germany in aeronautics is largely influenced by this work, and by the knowledge which you let the rest of the world participate in so liberally.

"When we started, two to three years ago, to construct our research institutes and the facilities shown to you by moving pictures this afternoon, the organizations and the establishments in this country served us as an example."

Colonel Vincenzo Coppola, Air Attaché of the Royal Italian Embassy, said:

"As the representative of Italy I have the honor to extend my country's sincerest congratulations to the eminent recipient of the Daniel Guggenheim Medal. Those of us who have specialized in this new and ever-emerging science full well appreciate that Dr. Lewis exemplifies the best there is among those outstanding minds who have startled the world with the unfolding of new scientific wonders of air navigation. His name will ever be memorable as a pioneer in the advancement of this science.

"Italy has been very attentive to the problems of aeronautics, and has nurtured the growth of the science. My countrymen have been mindful of its importance in the advancement of better international relations. The work of Dr. Lewis inevitably points the way to more kindly human relationships as the barriers of space and time are broken down and citizens of distant nations may commingle after the passing of short hours. Thus, his work is not important alone in the realm of the applied sciences, but is impressed with an international public interest of deepest significance."

Guy W. Vaughan, President of the Curtiss-Wright Corporation, spoke for the aircraft industry.

"Dr. Lewis has carried on successfully his research work along farsighted lines, much more so than has the aircraft industry. Industry has been handicapped by lack of funds to reach out far into the future and has to continually wonder where its next meal is coming from.

"I do not know how much the N.A.C.A. actually has cost but I do know that it is a figure far beyond that which this industry can hope to afford in addition to what it is spending today or can spend in the immediate future, if existing policies are pursued. To support this I refer to the earnings statement of any aircraft or engine company in the last five years and I happen to be familiar enough with manufacturing to know that some of them are extremely efficient in their operations.

"We have Dr. Lewis and his N.A.C.A. to keep us abreast of world development and in that we are most fortunate.

During the last five years the N.A.C.A. has made many contributions to the speed, efficiency and safety of airplanes. I feel that, particularly under the circumstances, Congress should be generous with the N.A.C.A. and continue to support this important branch of the Services as an essential to our national defense in any emergency that might arise, and, as far as the industry is concerned, it always will lend its wholehearted support and cooperation to the limit of its ability, and in appreciation of what Dr. Lewis has done for us in the past."

Hon. Edward P. Warner, Member of the National Advisory Committee for Aeronautics, said, in part:

"I have been asked to speak for the National Advisory Committee for Aeronautics. The resources of eulogy have been explored. Perhaps it would be best for me to simply say we have known him longer than any of you. We think we know him better. We agree with everything that has been said about him tonight.

"I think that the prestige of the Committee's laboratories and research work have increased the work of many men. Many have contributed; a number of them are here tonight from Langley Field. But there are two above all others: one is the Committee's chairman, who were it not for ill health would be standing here in my place tonight; the other you know—George William Lewis, born in 1882, graduated from Cornell University in 1908, successively instructor at Cornell, co-inventor of the Upton-Lewis machine for materials testing, Professor at Swarthmore, Director of the Clarkson Research, and in 1919, associated with the National Advisory Committee for Aeronautics. You know the story since 1919.

"The history of the National Advisory Committee divides easily into two periods. The period before it began to do its own research, or before the Committee's staff began to do research at Langley Field, and the period since. It is no mere coincidence that it also divides into almost exactly the same two periods at almost the same point on another basis, the period before George Lewis, and the period since.

"Slow-footed appreciation catches up at last with merit, that is why you are here tonight. That is why we shall all look back with pleasure upon having taken a part in this occasion, and that is why everybody who is now or who ever has been in any way associated with the work of the National Advisory Committee for Aeronautics takes especial pride and satisfaction in the great honor that you are paying to Dr. Lewis tonight."

Mr. Guggenheim then presented the Daniel Guggenheim Medal and the Certificate.

Dr. Lewis in accepting the award said, in part:

"I am overwhelmed with the generous praise that has been given me tonight, and it is difficult to express in mere words my appreciation in receiving this award. I appreciate in particular the action of the Board of Award of the Daniel Guggenheim Medal Fund in selecting me for the Medal for 1936.

"I realize, however, that the award was made largely in appreciation of the contributions that the National Advisory Committee made through the science and art of aeronautics.

"There is really no secret about the success of the Committee. It is a fact that the success has been largely due to the understanding and helpful cooperation of the Army Air Corps, of the Navy Bureau of Aeronautics, of the Bureau of Air Commerce, the Bureau of Standards, and all government agencies dealing with the problem of aeronautics. Without the helpful cooperation of the industry and of educational institutions we could not have at Langley Field the wonderful staff that we have there. I doubt very much whether we would have the highly trained personnel unless there had been established in 1926 the Daniel Guggenheim Fund for the Promotion of Aeronautics which established in the large universities, not only professorships, but also research equipment. We are indeed grateful to the other government agencies, to the industry, to the education institutions, for the success that we may have had in the past few years.

"I think we may all be proud of the accomplishments of America in adding to the science and art of aeronautics. We cannot attribute the success to any one organization. It belongs to us all. We cannot attribute it to any one man. I think the outstanding thing that has happened in the last ten years is the real spirit of cooperation between government agencies, industry and education. They have walked hand in hand, and we have all striven together to arrive at the point where we will advance and keep American aeronautics in the lead.

"I am happy to be associated with one of the government organizations, the National Advisory Committee for Aeronautics, and I am grateful for the privilege of service and association with the splendid group of men who make up the officers of the Committee and of the sub-committee.

"I am especially proud of my fellow-workers, and the personnel at the N.A.C.A., both at Langley Field and in Washington. Without their loyalty, ability and enthusiastic devotion to the progress of American aviation, the National Advisory Committee for Aeronautics could not have been a success, and this honor could not have come to me this night. In accepting the Guggenheim Medal, I want to express again my very deep appreciation to the many men here who have paid tribute to me. I think it was most generous. I express my appreciation to the officers of the Institute for arranging this wonderful occasion. I express my appreciation to all of you for coming. It has been a great pleasure to me, the high point of my life."

Mr. Guggenheim, in closing, thanked the organizations who had sent representatives to honor Dr. Lewis and the Institute for arranging the dinner.

The Next Five Years in Aviation

And First Showing of Films of Foreign Laboratories

As many guests were coming to New York to attend the dinner in honor of Dr. George W. Lewis, the committee in charge decided that it would be interesting to them to have a technical session during the afternoon of December 4. The American Society of Mechanical Engineers and the Society of Automotive Engineers were invited to cooperate and a joint committee was formed. About six hundred persons attended the meeting.

The Institute had requested several foreign governments to send moving pictures of their laboratories and wind tunnels to be shown at the Technical Session and at other meetings of the Institute. Films from England, France, German and Italy were received.

The first part of the afternoon session was devoted to a round table discussion on "The Next Five Years in Aviation." Dr. J. C. Hunsaker presided.

Abstracts of the discussion follow:

Graham Edgar

Ethyl Gasoline Corporation

FUELS

A little less than two years ago, I attempted to assume the thankless role of a prophet and predicted that fuels of substantially higher anti-knock value than those then available would shortly be manufactured and used and that these would contain synthetic products made from refinery gases. Experience since that time has, at least, partially verified this prediction, since during the current year, several million gallons of Aviation fuel of 100 octane number have been used and at least three oil refiners are producing such fuels.

In predicting probable progress for the next five years, I see no reason to believe that this trend will not continue and I shall, therefore, make the following rather definite predictions:—

(1) Within the next five years, fuels of 100 octane number will be as generally used as fuels of 87 octane number are used today, and fuels of substantially better than 100 octane number will be used where conditions seem to justify them.

(2) These fuels will consist of blends of gasoline, anti-knock agents and synthetic products produced from refinery gases.

(3) Advantage of these high anti-knock fuels will be taken in two different ways or by a combination of the two:— (a) For military and racing purposes and, perhaps, for short haul commercial work, increased super-charging with relatively little increase in compression ratio will be employed. Under these conditions, increases of horse-power per cubic inch of 25 to 50% above those now attained with commercial fuels will be realized. (b) Where fuel consumption is important, as for long distance commercial flying or for long range bombers, increased compression ratio will be employed instead of increased super-charge. Under these conditions, fuel consumptions of 0.35 to 0.37 pounds per brake horse power hour will be commonly obtained and consumptions substantially better than this will be obtained when sufficiently important.

(c) Various combinations of increased super-charge and increased compression ratio will also be employed according to the specific needs of the service.

(4) The diesel engine, in the face of competition produced by the development cited above, will make little or no progress in aviation during the next five years with the possible exception of the at present unexplored field of engines of 2,000 horse power and above, or unless improvements in diesel fuels take place somewhat equivalent to those which have occurred in the carbureted fuels.

DISCUSSION

In answer to two questions, it was pointed out that in order to prevent fuels from boiling in very high altitude flying, it would probably be necessary to use tanks capable of standing a certain amount of internal pressure and that quite possibly direct fuel injection would be necessary to solve the problems of boiling in the fuel induction system itself.

It was also pointed out that it would be necessary to develop some satisfactory scale of anti-knock fuel extending well above 100 octane number but that the principle which will be employed for this purpose cannot be predicted at the present time.

Roland Chilton

Wright Aeronautical Corporation

DIESEL ENGINES

I had intended to evaluate the present relative cruising fuel consumptions of gasoline and Diesel engines at .40 and .35 lb./hp./hr. respectively and to suggest that if the recent relative rates of improvement continue, the gasoline engine will meet the Diesel engine in a few years. However, the previous speakers are so much more optimistic for the gasoline engine than I was prepared to be, that thye have eliminated the 12% advantage which I was willing to concede to the Diesel engine. If we were discussing that part of operating expense represented by the fuel, the argument depends on the cost ratios of high octane gasoline and Diesel engine oil and here again it appears that the margin will decrease.

However, at the moment, and for the next few years, the urge to the Diesel engine is not on the grounds of cost economy but on fuel weight economy. The immediate objective is to attain a cruising range of about 2400 miles with reasonable payload and head wind reserve. The latest equipment is at or near this objective with .40 fuel consumption.

It must be conceded that these recent drastic reductions in cruising gasoline consumptions have been obtained secondarily by advances in the engine itself and primarily by improvement in operating technique, principally in the development of exhaust gas analyzers, automatic altitude controls and improved flight control. One advantage of the Diesel engine is that it is much less sensitive to operating control in maintaining its specified fuel consumption.

In current airline operation on this Continent, actual monthly averages of .45 lbs./hp./hr. fuel consumption, including spillage, warm-up and rich mixture take-off and climb, is now being realized as a routine matter. For long hops, under controlled conditions, cruising consumptions of .40 are being reported.

In predicting future trends, we must be guided by the direction of developments in the past. In the last five years the overall performance of airplanes has increased at an extra-

ordinary rate. The current two engine, smooth wing transport monoplane is about twice as fast as its predecessors of five years ago, comprising large biplanes, with engines, struts, wires, landing gears and lots of other apparatus strung outdoors. The output of engines has been increased during this period but, of course, we are using only a fraction of the eight times power loading that would be necessary to achieve this double speed by mere engine horsepower.

Even if we discount the fuel consumption predictions we have heard this afternoon and grant the 12% Diesel engine advantage that I was ready to concede, we still have to realize that this is a small increase in efficiency compared to what has been done aerodynamically in the past five years. For example, the increase in take-off loading, due to constant speed propellers, permitting full engine output at take-off, if put into fuel capacity, would amount to a great deal more than 12%. A 12% further increase in cruising speed, with current power factors, is a small advance compared to that already obtained by retractable landing gears or by the increased wing loadings permitted by landing flaps.

When the aerodynamic people develop a variable camber or other type of wing which does as much good on take-off as current flap devices do for landing, that again will represent more fuel capacity than would be saved by the Diesel engine even on the most pessimistic figures that we have had suggested today.

In reviewing that part of the extraordinary advance of the last five years, which is due to engines, I am forced to limit the major items to a substantial increase in take-off ratings, improvements in cowling and nacelle locations and a drastic improvement in actual cruising fuel consumption, and of these items the cowling and nacelle are more aerodynamic than engine matters. In spite of this, there was, especially in Europe, an impression that the performance of the high speed skin stressed monoplane of moderate wing thickness, which was pioneered in this country, was to a large extent, to be credited to improved engines. In the sense of reliability, take-off power and single engine performance, substantial advances have been made, but applied to the five year old biplanes with everything outdoors, this horsepower increase would have amounted to but a few per cent in air speed.

There appears no doubt that wing loadings will continue to increase as improvements in mechanized air foils increase the maximum to minimum speed ratio and this improvement will result in higher take-off loads and increased cruising speeds which, in my opinion, will increase the ultimate range much faster than will improvements in current engines or than the development and availability of Diesel engines in the large sizes demanded for trans-oceanic service.

I must apologize for having said nothing about Diesel engine construction in these remarks for which my excuse is that I have never designed, constructed or tested any engine of this type.

Alexander Klemin

New York University

Stability and Control

There has been much talk in the last two years of eliminating either the rudder or the ailerons, preferably the rudder, and so flying with only one control. The prediction is made that this elimination of the controls will never be practical. There occur in flying unexpected circumstances where both rudder and aileron are scarcely enough to cope with difficulties. Designers have already built machines which can normally fly with only aileron or only rudder but they will never abandon either of these controls. It is quite conceivable however that the problem of coordination of feet on the rudder bar and hands on the control stick may be met on small private ships by so arranging the control system that only the hands will be used. A column may be moved back and forth for elevator motion, the column may swing from side to side for aileron control, and a wheel like that of the automobile will be turned for rudder actuation.

Still another problem of vast importance will come when very large ships are built. The control surfaces of a modern clipper ship are as large as the wings of the whole airplane of 10 or 15 years back. Naturally as the control surfaces increase in size the power required to operate them grows continually. Hitherto aeronautical engineers have found ways of maintaining manual control. They have used a variety of devices to this end such as aerodynamic balancing of the control surfaces, tabs or trimmers, servo or auxiliary surfaces. But this evidently cannot continue indefinitely. There is a great advantage in purely manual control, since the pilot thus has a feel of the ship. But it is too much to hope for that manual control can be continued as ships grow indefinitely in size. Even to-day hydraulic remote control systems are being built and it can be safely predicted that in the next five years when still bigger ships will be built that in such ships manual control will disappear and auxiliary systems, either hydraulic or electrical in type, will be universally used.

The maneuverability of airplanes of similar aerodynamic and geometric design decreases with size. When very large aircraft are built the longitudinal maneuverability may become totally insufficient. It would then become necessary to start the landing glide many miles ahead of the airport, or to build airports of enormous extent. Or what is much more likely designers will make deliberate efforts to decrease the magnitude of the moment of inertia of the airplane about its transverse axis, by concentrating passengers or other useful load close to the center of gravity for example. An interesting challenge to design ingenuity will be offered by this problem. Maneuverability about a vertical or normal axis will probably be sought by making use of propeller thrust on either side of the fuselage. Maneuverability about the longitudinal axis may have to be sacrificed to some extent.

When an automatic pilot is employed, it endeavors to give complete angular restraint. This introduces conflict between the action of the automatic pilot and the inherent stability of the airplane. Thus if a vertical upward gust strikes an airplane, the inherent stability tends to nose the airplane down, while the automatic pilot tries to keep the longitudinal axis horizontal. Similar conflict may occur in the matter of side gusts, or side slips. It is conceivable therefore that the wide employment of the automatic pilot may lead to important changes in airplane design from a stability point of view. Aircraft intended for use with a gyro pilot may be given far less inherent static stability, or even be designed to be "neutrally" stable.

I. I. Sikorsky

Sikorsky Aircraft

Size and Performance of Aircraft

Modern technique offers possibilities for the construction of aircraft of considerable size. For example, it is believed that a million pound airplane, carrying 1000 passengers, could be produced before 1950. It is doubtful, however, whether this size will prove practical at this or even at a reasonably remote date. The characteristics of air transport with its high speed necessitates frequent departures in order to make the passenger and mail service really valuable and useful. Therefore, it appears probable that a larger number of aircraft of reasonable dimensions would do a better job and that the size of the aircraft will be controlled by economic factors and traffic requirements rather than by engineering possibilities. However, it is most probable that the airliner of the near future will be much larger than the

average present ships. The efficiency of an air transport as a useful load carrier depends not only on its payload capacity in units of weight, but at present just as much on the useful volume available for passengers and load.

In this respect the larger aircraft has considerable advantages because, briefly, the resistance of the body which carries passengers and load increases less than in proportion to the square of linear dimension, while the useful volume increases more than in proposition to the cube of the same dimension. Furthermore, the larger transport would still need practically the same flying crew, radio, navigation and other equipment. All these and several other considerations point to aircraft, if not of giant size, at least considerably larger than modern ships. It is most certain that planes of 100,000 lbs. and more will be flying or at least under construction during the coming five years. The introduction of such ships will contribute greatly to the coming vast expansion of air transportation.

The three existing basic types of aircraft, namely, the landplane, flying boat and amphibian, will all remain in their respective geographic fields of operation. With reference to their efficiency, while the landplane is and will remain the most efficient and least expensive of the three, the difference in speed and operating efficiency will become less pronounced in ships of larger size. Therefore, the flying boat will remain a very important factor of transportation, offering in large sizes an efficiency and speed very closely approaching that of a corresponding landplane and in certain cases offering substantial operating advantages.

With reference to the number and location of power units, the four engine transport, with all motors situated in one horizontal line, will remain the backbone of all major transport equipment during the next five years.

With reference to speed, the following general ideas can be expressed. At the present time, an operating speed of 225 miles per hour for leading land transports and 175 miles per hour for long range flying boats has been approached, and in some cases exceeded. This means that the airliner is 3 to 4 times faster than the best train, while the flying boat is 5 to 6 times faster than the latest steamship. While this speed appears sufficient to justify air travel, yet the coming years will bring further increase in operating speed.

It appears probable that the speed of 525 miles per hour mentioned by Dr. Lewis as a possible maximum speed for aircraft could be approached within the coming five years, providing a considerable amount of expensive research work can be done.

With respect to jet propulsion or rocket driven aircraft, neither of them appear to be around the corner.

Substantial progress may be expected in this line in the near future. It is now possible to design and build airliners capable of being operated in non-stop flights across the longest practical transoceanic air routes. This also opens the way to military possibilities of great importance.

It is expected that during the coming five years pioneering work will be done and actual airline operations established at reasonably high altitudes, such as 20,000 or 25,000 ft. At this altitude it will be possible to obtain the major benefits of high flying, namely, almost continuous clear weather and a substantial increase in operating speed. A certain supercharging of the cabin will be necessary, but the loss of pressure for any reason would not be fatal if the plane has provisions for supplying oxygen for that emergency.

Stratosphere flying at 50,000 or 60,000 ft. altitude or even higher will probably be studied during these five years and might prove to be very interesting from the scientific, as well as military, standpoint. It is questionable whether any substantial part of the regular airline travel will be done at this altitude in the not too remote future. While it is possible from an engineering standpoint, yet it appears that various difficulties, maintenance complications, as well as increased cost and hazards would be greater than the practical advantages of this type of operation.

Flying along established air lines is now a routine way of traveling across every continent and between most of the major cities. Before the end of five years the same will become true with respect to major transoceanic routes of the world. It is probable that some of the transport or excursion airlines will even run across the Polar regions. This great development of all existing branches of aircraft will result in a further and most interesting and encouraging expansion of activities connected with aircraft industry, operation and science.

William Littlewood

American Airlines

Progress in Airplane Aerodynamics

Practical progress to date in airplane aerodynamics must be measured by a summary of those arrangements and features which are incorporated in the latest airplanes constructed.

The commercial and military trend toward the low-wing monoplane type has been obvious. The general adoption of retractable landing gears and floats is noted. For such fixed gears as are used, the best known principles of fairing and streamlining are being applied. Toward the improvement of airplane speed range and control, wing flaps of the plain hinged type have been commonly adopted. The increasing use of constant speed propellers of greater pitch range, and the rating of engines at higher take-off powers and speeds, have supplemented the use of flaps and clean design to permit the attainment of higher wing and power loadings, and increased speed range. Consistent with other design considerations, engine installations are found to conform more nearly to the best arrangements determined by extensive N.A.C.A. research. Air-cooled radial engines predominate and with them true or modified N.A.C.A. engine cowls are in general use.

All metal airplane construction of the internally braced, smooth skin type has become increasingly prominent, and with it the elimination of external struts, wires, and fittings, and the provision of carefully designed fairings and fillets have naturally reduced drag, and have thereby improved aerodynamic efficiency. More efficient wing sections have been developed. Fully retractable or built-in landing lights are in general use. The development of suitable vacuum pumps has eliminated the necessity for external venturii as sources of vacuum supply. The air-driven generator has been replaced by an engine-driven unit. Innumerable refinements have been made in detail design to improve cleanness.

It has been remarked that the curve of aerodynamic progress is rapidly becoming asymptotic to the line of ultimate achievement. The thought expressed is that no major improvements are likely, and that from this point forward development will be largely by further refinement of detail, each small gain being made only at the expense of intensive research, and being incorporated in practical airplanes only by extreme refinement of design, and by super care in manufacturing detail and inspection, the benefits achieved being retained in operation only by extremely careful maintenance.

This thought neglects at least two important considerations; firstly, that there are essentially a family of curves of practical aerodynamic progress, each one applying to a particular type of airplane and each measuring differently the importance of certain aerodynamic refinements; and, secondly, that numerous valuable improvements are already past the research stage, but have not yet been fully applied to practical use because of economic pressure in manufacturing, or the neces-

sity of further collaboration between designer and fabricator, or material and equipment manufacturers.

The basic problems are still to achieve in the finished airplane the maximum usable speed range, that is, the highest ratio of maxium to minimum controllable airplane speeds; and to accomplish the greatest ratio of lift to drag for most efficient high speed operation, as well as desired variations in that ratio to best meet other operating requirements.

We have been so gratified by the improvements which have been realized in recent years, that we may be inclined to give far too little weight to the possibilities which remain, many of which will become practical realities during the next five years. Each gain in aerodynamic efficiency or improved aerodynamic qualities, is a definite contribution to even greater safety of operation and reduction of operating costs, as well as being a step toward the achievement of hitherto impossible load carrying and speed performances. These are basic factors in the advancement of aviation.

It is felt that airplanes to be produced within the next five years will incorporate aerodynamic improvements in all of the following characteristics:—(1) Speed Range—Use of high lift and improved control devices. (2) Use of feathering and reversible propellers. (3) Landing gear flight condition and operation. (4) Complete closure of wheel well and other openings. (5) Windshield design. (6) Landing and navigation light installations. (7) Elimination of external radio antennae. (8) Engine carburetor or other air intakes. (9) Oil cooling or other radiator installations. (10) De-icer installations. (11) Fuselage shapes. (12) Smoothness of external surfaces. (13) Airspeed installations. (14) Engine cooling method.

With the exception of the adoption of improved high lift and control devices, the other aerodynamic improvements listed are probably not individually of great significance. However, they are collectively of the greatest importance and that importance will increase rapidly with the inevitable advance of operating speeds to be achieved within the next five years.

B. C. Boulton

The Glenn L. Martin Company

Aircraft Structures

There has been a general speculative interest in very large aircraft for many years but now such aircraft are about to become an actuality and be flying over both great oceans with payloads not seriously considered possible two or three years ago. Hence, the subject is of vital interest as it has a profound bearing on intercontinental air transportation.

The reasons for this increased efficiency are improvements in the aerodynamic characteristics of the airplane and developments in the power plant and structure. Aerodynamically there is a marked improvement with increased size due to the greater predominance of the wing with respect to the body and power plant nacelles. Our knowledge of aerodynamic forms and their proper combination to reduce further mutual interference, has increased largely within the last year or two.

There has been marked improvement in three basic power plant characteristics: weight in pounds per horsepower, increased power per unit and particularly decreased specific fuel consumption. In the case of a typical 20,000 lb. airplane designed several years ago, the power plant formed about 18% of the gross weight, whereas on a modern 100,000 lb. airplane the power plant amounts to only 12% of the gross weight.

The decrease in structural weight is due to three factors: improved structural materials, increased knowledge of applied loads and of efficient disposition of material, and decreased structural weights with size.

The present discussion is based upon a study of actual weights of several aircraft and on an extrapolation of these data following sound fundamental tendencies. It is difficult in such a study to evaluate separately the three factors noted that affect the structural weights. The discussion is further limited primarily to flying boats which have a definite advantage over landplanes in that the body is used for landing instead of a heavy landing gear with its retracting mechanism.

The important structural items to consider are: wing, tail, hull and nacelles, means for lateral balance on the water, and fixed equipment. The wing is the most important unit and with increased gross weight it becomes a larger percentage of the structural weight. There is a basic tendency for wing loading to increase with the gross weight, approximately as

$$\sqrt[4]{\text{gross weight}}.$$

The wing weight is given closely by the formula

$$W_w = K\sqrt{\text{load factor} \times \text{gross weight} \times \text{wing area} \times \text{span}}$$

"K" as determined from a large number of cantilever wings, decreases slowly as the gross weight increases.

It is interesting to consider the proportions and unit weights that are obtained if an aspect ratio of 10 and a load factor of 4.25 are maintained and the wing loading varies as noted above.

Gross Weight	Wing Loading	Wing Span	Wt./sq.ft.
20,000 lbs.	21	98	3.0
50,000 lbs.	26	138	3.6
100,000 lbs.	31	180	4.0
200,000 lbs.	37	233	4.5

Based on the assumptions given, the total wing weight remains almost a constant per cent of the gross weight, decreasing from 14.5% for a 20,000 lb. airplane to 12% for a 200,000 lb. airplane.

The tail surface weight is practically a constant percentage, 13-14%, of the wing weight.

The body group or hull and nacelles decrease markedly as a per cent of the gross weight as the latter increases due to the following factors: for most efficient seating and sleeping a hull width of 12.5-13.0 feet is sufficient and for this purpose there is no gain in a greater beam. The hull beam required for take-off increases only as $\sqrt[3]{\text{gross weight}}$ and furthermore longer take-offs are considered permissible for very large airplanes. Since a large portion of the disposable load is in the very concentrated form of fuel the hull volume does not have to increase beyond normal structural requirements to accommodate cargo and passengers. This, of course, is a matter upon which there is a considerable difference of opinion and undoubtedly if unusual luxurious quarters are provided, a weight and aerodynamic penalty is paid. It should be borne in mind, however, in this connection, that with the high cruising speeds possible even for transatlantic operation, the normal trip should not be over twenty hours. Obviously less commodious accommodations are necessary than in the case of the dirigible where sixty hours is the usual time for such a trip. Because of the increase in engine power without increase in diameter, the weight of engine nacelles is a decreasing percentage of the hull weight as the gross weight becomes larger.

The weight of floats for hydrodynamic balance may be considered a constant percentage, about 10-12%, of the hull weight. Fixed equipment is a nearly constant percentage of the gross weight, decreasing slowly from about 6% for a 20,000 lb. airplane to 5% for a 100,000 lb. airplane.

In conclusion it may be stated that the structural weight of flying boats decreases with increasing size being about 33%, 28% and 25% of the gross weight respectively for 20,000, 50,000 and 100,000 lb. airplanes. The weight empty decreases between 1½ and 2 per cent per 10,000 lbs. increase in gross weight, at least up to 100,000 lb. size. At some larger size the curve must reach a minimum and then perhaps go up. This

definite tendency coupled with great progress made in reduction in the specific fuel consumption, insures the profitable operation of non-stop transatlantic airlines as soon as the airplanes, now in the design stage, can be built.

Geodetic Construction: We have studied with great interest all available articles on the subject and have reached the conclusion that this construction is much over-rated and is inherently inferior from the weight and cost standpoints and from the important angle of reasonably fast and accurate analysis to the best of our stressed skin structures.

The stiffness and strength of a structure are proportional to the modulus of elasticity of the material, the moment of inertia and section modulus of the section and the crippling or maximum elastic unit stress of the material.

The modulus of elasticity is independent of the type of construction. The material of our stressed skin structure is disposed at the surface and hence the moment of inertia and section modulus of the section are the maximum for a given area of material that the outline form of the structure permits. The crippling stresses with the best conventional structures are considerably higher or at least equal to those for the elements of geodetic construction which are channel or "Z" members, though the tubes could be used.

The multitudinous fittings employed in the geodetic construction at each intersection of the interlacing members add much to the weight and cost of the structure.

The method of analysis is long and difficult and probably inaccurate at least if short cuts are used, leading to structural inefficiency.

E. P. Warner presided at the showing of the films from Europe and introduced the speakers who described each film. The order of presentation was alphabetical.

The English film on Aeronautical Research was described by Group Captain T. E. B. Howe, British Air Attaché to the United States. The film showed a model in the vertical spinning tunnel at Farnborough, model seaplanes in the seaplane tank, several air flow pictures, the 24 foot wind tunnel and other views of the Royal Aircraft Establishment.

Colonel Norbert Champsaur, Air Attaché of France to the United States, presented the French film. He explained that through a misunderstanding his government had sent two technical films instead of views of French laboratories. He said that one would be shown at the meeting and the other reserved for showing at the Annual Meeting of the Institute. He then explained a most interesting film showing the *Hydraulic Analogy of the Motion of a Compressible Fluid and Production of Shock Waves.*

Dr.-Ing. F. Seewald, Director of the Deutsche Versuchsanstalt für Luftfahrt, at Berlin-Adlershof, who had come from Germany to honor Dr. Lewis, presented the German film. It showed the Institute for Aeronautical Measuring Technique and Flight Meteorology at the Brunswick Technical Academy, The German Research Institute for Gliding at Darmstadt, the Aerodynamic Institute at Aachen, The Institute for Hydro-aviation at Hamburg, The Research Institute for Engines at Stuttgart, and the Aerodynamic Research Laboratory at Göttingen with its new high pressure wind tunnel. The audience was taken on a tour of the new D. V. L. and shown the new buildings, the large wind tunnel, the spinning tunnel, the propeller measuring test stand, and many research investigations in the laboratories.

Colonel Vincenzo Coppola Air Attaché of Italy, presented the film showing the new aeronautical city of Guidonia. After a general view of the exterior of the buildings was shown, views of the following were given with elaborate pictorial demonstrations. The Pavillion for Aerodynamics, the wind tunnel hall housing four 2 m. wind tunnels, the vertical wind tunnel, the Hyperacoustic Stratospheric wind tunnel, the double return wind tunnel and the Hydrodynamic tank.

These moving pictures, which took an hour and a half to show, cannot be described in detail in this issue. The Institute is greatly indebted to the countries which have with such generosity disclosed for the benefit of American aeronautical specialists the latest developments in wind tunnels and laboratories abroad. These films are being prepared so that they may be shown again to members in New York at the Annual Meeting of the Institute and elsewhere.

Institute Notes

The Fifth Annual Meeting of the Institute

The Fifth Annual Meeting of the Institute of the Aeronautical Sciences will be held at the Physics Building, Columbia University, New York City, on Wednesday, Thursday and Friday, January 27-29, 1937.

The Meetings Committee, which is in charge of planning the sessions, has again provided three days for the Fifth Annual Meeting. An enlarged program, which follows, is planned.

On Thursday, January 28th, at 5 p.m., the Annual Meeting will be held. Reports of Officers will be made and the election of new members of the Council will be held.

On Thursday, January 28th, the Annual Dinner will be held. At that time the *Sylvanus Albert Reed Award* and the *Lawrence B. Sperry Award* will be presented.

Program

Wednesday, January 27.

10:00—12:30 p.m. Simultaneous sessions on *"Structural Problems and Aircraft Design"* and *"Instruments, Radio, Radio-Meteorograph."*

2:00—3:30 p.m. Technical session and discussion on *"Fluid Mechanics."*

3:30—5:00 p.m. *"Long Range Seaplane and Airship Problems."*

5:00—7:00 p.m. Showing of films from England, France, Germany and Italy.

Thursday, January 28.

10:00—12:30 p.m. Simultaneous sessions on *"Engines and Fuels"* and *"Meteorology."*

2:00—4:30 p.m. Technical Session and Discussion on *"General Aerodynamics."*

5:00 p.m. Annual Meeting, Institute of the Aeronautical Sciences.

Evening: Annual Dinner, Institute of the Aeronautical Sciences.

Friday, January 29.

10:00—12:30 p.m. Technical Session and Discussion on *"Airplane Stability and Performance."*

2:00—4:30 p.m. Technical Session and Discussion on *"Flying Properties and Flight Testing."*

A complete program will be sent all members during the month of December.

Student Branches

University of Michigan. A meeting of this Student Branch of the Institute was held on Thursday, November 7. Over sixty members were present.

The speaker of the evening, C. L. Johnson, Project Engineer of the Lockheed Aircraft Corporation, lectured on *"Flight Testing and Associated Problems."* Among those present attending the meeting was Ralph Upson, designer of the all-metal Navy blimp constructed in Detroit. The entire staff of the University of Michigan Aeronautical Engineering Department was present.

University of Minnesota. A meeting of this Student Branch was held on November 6.

On November 11, at the invitation of the Student Branch of the American Society of Mechanical Engineers, the members of the Institute Student Branch attended a showing of a film entitled *"The Making of Alloy Steels."*

At a meeting held on November 25, an instructive film on *"Back of the Weather Forecast"* was shown. It showed how the U. S. Weather Bureau gathers weather data and makes the weather map, which is sent throughout the country.

Meetings

December 28, 1936-January 1, 1937. American Association for the Advancement of Science Annual Meeting and Science Exhibition, Atlantic City.

December 29, 1936, 10 a.m. Aeronautic Meeting of the I.Ae.S., Atlantic City.

January 27-29, 1937. Annual Meeting, I.Ae.S., Columbia University, New York.

Necrology

Juan de la Cierva, an Associate Fellow of the Institute, died December 9, 1936, as the result of an accident to a transport airplane shortly after leaving Croydon, England.

Juan de la Cierva y Codorniu was born at Murcia in Spain on September 21, 1895. He was educated at high school first at Murcia and then in Madrid, afterwards becoming an Ingeniero de Caminos, Canales y Puertos at the Special Technical College in Madrid, where he graduated in 1919.

His first work in aeronautics dates back as far as 1910, when he built two gliders with the cooperation of some friends of his own age. While very little success was obtained they were not discouraged, and in 1911 they started the construction of a mechanically propelled aeroplane. It was the first Spanish built aeroplane to take properly to the air.

It was shortly after this that he passed successfully his entrance examinations to the Escuela Especial de Ingenieros de Caminos, Canales y Puertos, where he spent the next six years of his life, during which period he tried to learn privately as much as possible about theoretical aerodynamics.

In 1919 he commenced to study the problem of helicopter design, and five years later his first successful model was tested near Madrid. By 1925, he was ready to exhibit his success, having produced an Autogiro capable of showing fully the possibilities of his system. After demonstrating this machine in England towards the end of the same year, the Cierva Autogiro Company, Ltd., was formed.

Apart from his technical activities in the field of aeronautics, Juan de la Cierva took an active part for a short time in Spanish politics, being elected Member of Parliament in 1919 and again in 1922.

In the United States, Harold Pitcairn organized the Autogiro Company of America. Dr. Cierva received many honors. He was given an honorary degree of Doctor of Science by the Stevens Institute of Technology. In 1926 he was awarded the Fereration Aeronautique Internationale's prize, winning the same organization's gold medal in 1932. In 1931 his invention was awarded the Collier Aviation Prize as "the most revolutionary development in heavier-than-air craft since the first flight of the Wright brothers in 1903." In that same year, jointly with Mr. Harold F. Pitcairn, his American associate, the John Scott Medal was conferred upon him by the City of Philadelphia. In 1932 he was awarded the Daniel Guggenheim Medal "For development of the theory and practice of the autogiro." He was a Fellow of the Royal Aeronautical Society.

Letters to the Editor

Dear Sir: November 18, 1936

(Electrically-Strain-Sensitive) Ess Strips

A practical method for the measurement of strains due to rapidly varying loads, particularly in moving parts, has long been needed. One of the most promising schemes for measurement has been to translate the strain into an electrical quantity and measure its variations with an oscillograph, usually after some degree of electrical amplification.

The change in electrical resistance due to change of load on a carbon pile has long been known, as has also the change in induction due to varying the air gap in an alternating current magnet. Both these methods are established as strain gauges in the "Telemeter" of the Baldwin Southwark Company.

Another variable resistance instrument is the Carlson gauge utilizing the change in resistance of fine wire under heavy tension. This device is particularly valuable under long-time static conditions on account of its inherently small zero shift. The corresponding instrument using variable inductance, has been introduced by the General Electric Company as a precision measuring gauge.

Variable capacity, in conjunction with a high frequency oscillator has been utilized in a variety of circuits for measuring small displacements, either static or dynamic under the general name of ultramicrometer. Another variable inductance gauge makes use of the change in permeability of magnetically "soft" iron. The piezo-electric properties of both quartz and Rochelle salt have been used for laboratory purposes, but no commercial instrument on this basis has been prominent.

In all of the devices mentioned, the "pick up" unit has usually been too heavy and often too frail to attach to such parts as airplane propeller blades, or to parts subject to impact load.

One solution has been suggested by E. H. Hull of the General Electric Company, following a lead given in Nature*. He introduced a sensitive paint, of graphite particles either with or without binder, in which the changes in electric resistance under cyclic loading bore practically a linear relation to strain, irrespective of frequency. He showed that the paint could be used for short gauge lengths of the order of $\frac{1}{4}$ inch.

The paint method seemed to offer great promise for the propeller problem, and the general method was brought to the attention of the Hamilton Standard Propeller Company. Simultaneously, an investigation of the whole subject was begun at the Massachusetts Institute of Technology in cooperation with the Propeller Company. Several methods of applying the paint as well as different paint mixtures suitable for dynamic conditions were found, but no solution of the problem of static or slowly changing strain measurements. Mechanical hysteresis, temperature and moisture, made static calibration unsatisfactory. This was in line with the General Electric results.

Leaving out the question of very short gauge lengths, a matter well investigated at the General Electric Company, the Massachusetts Institute of Technology concentrated on the preparation of strips of strain-sensitive material which could be precalibrated, attached to a metal surface and removed therefrom without disturbance of the calibration, and which would be suitable both under static and dynamic conditions.

Many different insulating materials, mixed with graphite or carbon were tried, among others, graphite and sulphur. Thin paper with the sulphur mixture melted in was found to be practical. Meanwhile Hamilton Standard found suitable characteristics in baked carbon resistor units as used in the radio industry. At the Institute we had also tried pencil leads and found good strain sensitivity, but difficulty with the lead in wires.

Plastics, such as bakelite loaded with carbon, were also investigated and with the assistance of the Arthur D. Little laboratories a successful procedure has been evolved for producing loaded bakelite sheet. It was found possible to process strain-sensitive bakelite between thin sheets of pure insulating bakelite, with molded-in connections.

These strips have been found sensitive to strains of the order of .0002 in. and reasonably free from moisture and temperature effects. Their response to high frequency vibration, constancy of zero, methods of attachment and use for measurement of combined stress is now being studied. A highly successful form of amplifier and recording oscillograph has been developed by Prof. C. Stark Draper, and with this the new Ess strip (electrically-strain-sensitive) is being used by the Hamilton Standard Propeller Company.

Suitable indicating and recording instruments are being studied for static and slowly fluctuating loads, where photographic recording is not necessary. It is expected that for recording strain at many points, as in analyzing static loads on airplane structures, the Ess strip will be found convenient. Exact limits of accuracy under dynamic conditions are not known, but present indications are that at least for cyclic strains the present construction is amply precise.

A. V. DEFOREST

Massachusetts Institute of Technology

A NOTE ON VISIBILITY OF VORTICES

Tip vortices in air, such as trail from wing tips, propeller blades and other surfaces of high local circulation can be made visible by smoke, and have infrequently been reported as visible in moist air. This latter phenomenon has been observed with models in a high velocity jet. Mr. George H. Tweney, a Student Member of the Institute of the University of Detroit, reported that tip vortices could be seen trailing the airplanes on turns at the Mitchell Trophy Race at Selfridge Field on October 17. Similar statements have been made regarding other races. The following letter is in response to an inquiry as to what was actually seen at Los Angeles last September.

THE EDITOR

Dear Sir:

In connection with your inquiry regarding tip vortices, the following observations, which were made by many of the spectators at the National Air Races last September in Los Angeles, may be of interest. On several occasions definite indications of tip vortices were visible as machines passed the grandstand. The phenomenon was particularly noticeable when six Boeing P-26 pursuit planes dove in single file and pulled up just in front of the grandstands into a steep climb. Just as the angle of attack was suddenly increased, vortices were plainly visible trailing downstream from the extreme tips of the wings. It was at first suspected that the planes were carrying smoke candles at the wing tips, but this was later discovered not to be the case. It appears that the atmospheric conditions were just such that when the lift coefficient was suddenly increased at the high diving speed, condensation of moisture occurred at the center of the trailing vortices, which made them visible. The phenomenon was particularly striking since it was repeated at intervals of a few seconds practically identically by all six planes.

This was the first time many of the spectators, including the writer, had ever seen the phenomenon of tip vortices so beautifully illustrated without any laboratory setup whatever.

CLARK B. MILLIKAN

California Institute of Technology

* A New Method for Measuring Mechanical Stresses at Higher Frequencies, A. Block, Nature, Aug. 10, 1935, p. 223.

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.

Aero Digest, 515 Madison Ave., New York City.

Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina

L'Aeronautique, 55 Quai des Grands-Augustins, Paris, France.

L'Aerophile, 7 Rue Saint-Lazare, Paris, France.

The Aeroplane, 175 Piccadilly, London, W.1, England.

L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.

Les Ailes, 77 Boulevard Malesherbes, Paris, France.

Aircraft Engineering, 2 Bloomsbury Place, London, E.C.1, England.

Air Law Review, Washington Square East, New York City.

Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.

Astronautics, American Rocket Society, 31 West 86th Street, New York, N. Y.

Aviation, 330 West 42nd St., New York City.

L'Aviazione, Corso Umberto 504, Rome, Italy.

Boletin de Aeronautica Civil, Calle Azcuenaga 923, Buenos Aires, Argentina.

Boletin Oficial de la Direccion General de Aeronautica, Magdalena 12, Madrid, Spain.

Bulletin du Service Technique de l'Aeronautique, 72 chaussee de Waterloo, Rhode-Saint-Genese, Belgium.

Bulletin of the American Meteorological Society, Blue Hill Observatory, Milton, Massachusetts.

Bulletin Officiel du R.A.A., 6, Rue de Mezieres, Paris (6), France.

Bulletin Technique du Bureau Veritas, 31 rue Henri-Rochfort, Paris (17), France.

Canadian Aviation, Journal Building, Ottawa, Canada.

Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.

Les Fiches Aeronautiques, 6 rue Galilee, Paris, France.

Flight, Dorset House, Stamford St., London, S.E.1, England.

Flugwesen, Konviktska 22, Prague 1, Czechoslovakia.

The Gliding and Soaring Bulletin, Soaring Society of America, Pensacola, Florida.

Indian Aviation, P. O. Box 2361, Calcutta, India.

Interavia, 13, Corraterie, Geneva, Switzerland.

Journal of Air Law, Northwestern University, Chicago.

Journal of the Institute of Engineers, Australia, Science House, Gloucester and Essex Sts., Sydney, N. S. W., Australia.

Journal of Research of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.

Journal of Scientific Instruments, 1 Lowther Gardens, Exhibition Rd., London, S.W.7, England.

Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.

Letectvi, Celetna 13, Praha I, Czechoslovakia.

Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.

Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.

Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.

Model Airplane News, 551 Fifth Avenue, New York City.

Model Aviation, The American Academy for Model Aeronautics, 1733 RCA Building, Rockefeller Center, New York, N. Y.

Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.

Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.

National Aeronautic Magazine, Dupont Circle, Washington, D. C.

Official Aviation Guide, 608 S. Dearborn St., Chicago.

The Pilot, Grand Central Air Terminal, Glendale, California.

Il Politecnico, Via Spiga 32, Milan (2/7), Italy.

Popular Aviation, 608 S. Dearborn St., Chicago.

Proceedings of Institute of Radio Engineers, 330 W. 42d St., New York City.

Publications Scientifiques et Techniques du Ministère de l'Air, 55, Quai des Grands-Augustins, Paris, France.

Review of Scientific Instruments, 175 Fifth Ave., New York City.

Revista de Aeronautica, Ministerio de la Guerra, Apartado 1047, Madrid, Spain.

Revue de l'Armee de l'Air, 55 quai des Grands-Augustins, Paris, France.

Revue du Ministere de l'Air, 71 avenue des Champs-Elysees, Paris, (8), France.

Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.

The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.

Southern Flight, Ledger Building, Fort Worth, Texas. Texas.

Sportsman Pilot, 515 Madison Ave., New York City.

Technical News Bulletin of the National Bureau of Standards, U. S. Govt. Printing Office, Washington, D. C.

Technika Vosdushnogo Flota, U1. Radio 16, Moscow 16, U. S. S. R.

La Technique Aeronautique, 2 rue Blanche, Paris (9), France.

U. S. Air Services, Transportation Building, Washington, D. C.

Western Flying, 420 S. San Pedro St., Los Angeles, California.

Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin SW68, Germany.

Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Aerodynamic Effects on Oscillating Profiles. Aerodynamic field surrounding a vibrating wing. Recent research is reviewed and a method is developed for solving the problem. Results of an analysis leading to aerodynamic coefficients are given. L'Aerotecnica, August-September 1936, pages 652—655. 3 illus. 18 equations.

Aerodynamic Lift at Supersonic Speeds. A. Busemann. At supersonic speeds the wing of finite length possesses a marginal drag all or partially due to the wave resistance. In order to maintain low total frictional and wave resistance, it is necessary to use a small wing area and low angle of attack. These two requirements can be coupled only when directions of flow more sensitive to deviation are utilized and therefore the use of lifting surfaces with large sweepback is proposed. Formulas are developed for supersonic linear, cylindrical and conical flow applied to a wing. In the appendix the lift of a biplane at supersonic speeds is calculated. Long article. L'Aerotecnica, August-September 1936, pages 613–638. 16 illus. 57 equations.

Nature's Airplanes. S. F. Aaron. Examples of soaring flight and aerial propulsion of birds and flying squirrels. Scientific American, December 1936, pages 338–339. 4 illus.

Turbulent Fluid Motion. C. Ferrari. Reasons which lead the author to believe that turbulent phenomenology pertains entirely to the field of statistical mechanics and an explanation of the more recent and more important facts for reaching a statistical theory of turbulence. L'Aerotecnica, August–September 1936, pages 639–651. 6 illus. 7 equations.

The Problem of Resistance in a Compressible Fluid. T. Von Kárman. The discussion covers: Thermodynamic relations; mechanical similitude; general analysis of resistance; effect of compressibility on frictional resistance, on potential flow of a fluid around an obstacle at subsonic velocities, and on the resistance of the wake at subsonic velocities; approximate theory of wave resistance for two-dimensional motion; shock waves and a second approximation for supersonic two-dimensional flow around a body; and approximate theory of wave resistance of a spindle-shaped body of revolution. The exact equation for axially symmetrical flow is derived and other three-dimensional problems are taken up. Experimental results in the field of supersonic velocities are given and a limited case of high velocity in comparison with the velocity of sound is reviewed. Long article. L'Aerotecnica, August–September 1936, pages 575–615. 16 illus. 100 equations.

The National Physical Laboratory. Research on fluid motion, atmospheric turbulence and gusts, spinning and flutter, propeller design, and the compressibility effect. Review of investigations which are being carried on in the aerodynamics department. Continuation. Engineering, October 9, 1936, pages 381–383. 7 illus.

The Reynolds Number. B. A. Bakhmeteff. A simplified explanation of the significance of this quantity and examples of its use in aerodynamics and hydraulics. Mechanical Engineering, October 1936, pages 625–630. 12 illus. 20 equations.

Aircraft Design

Flaps and Pitching Moments. Simple method for estimating the change in center of pressure is developed with an analysis of results given in N.A.C.A. Report 539, R. & M. 1636, "Tests on Airfoil Flaps in the Compressed Air Tunnel," and R. & M. 1543, "Wing Tunnel Tests on Airfoils 38 and 48." Brief. Flight, Aircraft Engr. Sup., October 29, 1936, pages 21–22. 3 illus. 3 tables.

High Altitude Research. Program of research in high-altitude flight announced by T.W.A. with a few details of the plane and reference to the World altitude mark made by Squadron Leader Swain in connection with research for the Royal Air Force. Brief. Aviation, November 1936, pages 53–54. 4 illus.

How Fast? N. B. Moore and W. C. Rockefeller. Ultimate maximum speed at sea level. "Cost" of airplane speed is defined as the minimum thrust horsepower required per square foot of equivalent parasite area for any given sea-level speed. The limiting price set by the phenomenon of compressibility, the future record holder, and aircraft engines are discussed. The author urges acceleration in American development of compact air- and liquid-cooled in-line vee and horizontally-opposed engines not only for racing planes but also for pursuits and fighters. To be continued. Aviation, November 1936, pages 30–31. 5 illus.

The Ideal Airplane. H. Fassbender. The ideal airplane with movable lifting surface and possibilities for its development. The various means discussed for obtaining lift include: a rotating cylinder producing a Magnus effect, a rotating helicoidal spindle, flapping wings, swiftly flapping wings, and wheels with airfoils located at the rim. The methods considered for maintaining balance cover: parallel lifting propellers rotating in opposite directions, coaxial propellers rotating in opposite directions, propellers located at the ends of lifting propeller blades, and oblique tractor propellers. Abstract from Luftwissen No. 5. Rivista Aeronautica, September 1936, pages 348–354. 10 illus.

Modern Ideas. Recent developments in aeronautical research. The trend of opinion today is towards the "return flow" closed-jet type of wind tunnel because of the slight divergence in the parallel flow in the open-jet type. The Heinkel He-70 is considered to have the smoothest aircraft surface known to the author and has the lowest drag per wetted area of any machine in existence. Wings for very highspeed machines must be of symmetrical section as the depth of the wing above the center line is then reduced for the same depth of spar. Brief abstract of paper presented by E. F. Relf before the Royal Aeronautical Society. Aeroplane, October 21, 1936, page 518.

The "Pou" Situation. Results of tests on a scale model of the Pou-du-Ciel in a French wind tunnel, full-scale test results at Chalais-Meudon, and flying test results agree with those obtained in full-scale tests in the large wind tunnel at Farnborough. Explanation of the design and results of both the Mignet Pou and the Abbott-Baynes cantilever Pou. Flight, October 22, 1936, pages 404–407. 8 illus.

Preparing to Fly the Seven Seas. Boeing and Douglas announcements of flying boats capable of "aerial conquest of vast ocean distances." A few details. U. S. Air Services, November 1936, pages 17–18.

The SN-2 Experimental Airplane with Variable Surface. W. Schemeidler. The wing surface of the airplane described is variable in flight and the movable part of the wing does not enter into the fixed part but folds against the lower surface and clings to it. Description and results obtained in flight at Breslau airport. Abstract from Luftwissen No. 12. Rivista Aeronautica, September 1936, pages 347–348.

State Officials Trade Ideas with Federal Officers at N.A.S.A.O. Annual Convention. Features which the airplanes of the future should have are briefly outlined with abstracts of other papers presented before the National Association of State Aviation Officials. Aviation, November 1936, pages 24–26, 47.

Tapered Wings. G. V. Lachmann. Aerodynamic and structural features of tapered wings for airplanes. Wings of fairly high taper ratio (not exceeding a ratio of 4 to 5) are favored by the author because their structural economy is greater both from the point of view of strength in bending and stiffness against torque, and also because the reduction in damping affords more efficient lateral control. The fully stressed shell-type wing is considered superior to the design which has concentrated spar flanges, especially when the weight of the airplane is above 10 tons. Of the devices used to increase drag and lift, the author considers that the slotted flap offers the best all-around solution and compares its characteristics with those of other devices in use. The stalling of tapered wings, influence of the engine nacelles on longitudinal stability, use of trimming tabs, and mass-balancing the elevators are discussed. Various types of cantilever wing structures are taken up with advantages and disadvantages of each. Very long abstract of paper presented before the Royal Aeronautical Society with a review of the discussion following. Aeroplane, Aeronautical Engineering Supplement, October 14, 1936, pages 479–482. 9 illus. Flight, October 15, 1936, pages 380–382. 8 illus.

Flight on Rotating Wings. W. L. LePage. Inefficient utilization of power is considered as a cause of helicopter failure and a solution is proposed which consists of using the lifting rotor system itself as the means of forward propulsion. Mathematical relationships are given which enter into the conditions of level flight of translation of the rotary-wing machine using the tilted rotor axis as a means of propulsion. Mechanical complexity, excessive weight and parasite drag, instability and ineffective control of the helicopter are also considered. Concluded. Journal Franklin Institute, October 1936, pages 461–474. 5 illus.

Modern Helicopter Theory. V. Isacco. Principles of direct-lift flight. The author considers that the main advantage of the theory presented is that it can be applied to any method of flight, to any family of wing sections, and it takes account of the aspect ratio of the blades according to Prandtl's theory. Helicogyre, helicopter and autogiro flight are defined. Formulas are developed for induced velocity, incidence of the blades, number of revolutions, sustentative quality of a propeller, quality in horizontal translation with the drag due to translation, and for calculating the characteristics of a helicopter in sustentation. Formulas are also derived for ground effect, coupling of propellers, air draught perpendicular to the axis, vertical ascent and ceiling, vertical descent and autorotation, horizontal translation in helicogyre, helicopter and autogiro flight, and comparison with the airplane. As a practical example all the performances of a helicopter are calculated and the necessary investigation given to help in the choice of the best parameters. The author has been associated with the development of the Pescara helicogyre. Long article. To be continued. Aircraft Engineering, October 1936, pages 274–283. 16 illus. 3 tables. 66 equations.

Stress Analysis and Structures

Pounds or Pounds/Square Inch. F. R. Shanley. Strength-weight relationships in aircraft design. Stressed-skin structures are reduced to two basic types, the first in which failure occurs at some definite stress which is a function of material only, and the second in which failure occurs through instability of the structure depending on dimensions and elastic properties of the material. Strength-weight factors are derived for both types. Tables give the factors affecting strength and weight of shell-type structures having the same outside dimensions, and a comparison of various materials for "stability" type of failure. Aviation, November 1936, pages 27–29. 1 illus. 2 tables.

Analysis of Plate Examples by Difference Methods and the Superposition Principle. D. L. Holl. The membrane analogs of H. Marcus applied to some elementary cases of thin homogeneous isotropic square plates having central-point loads and various boundary conditions. The principle of superposition of deflection surfaces or equivalent stress

systems is utilized both by difference and differential methods. The correct critical stress at the center of the lower surface of the plate was obtained from a special thick-plate theory for a particular thickness-to-span ratio. The effect of this critical stress on the whole plate action is depicted for various boundary conditions. Journal Applied Mechanics, September 1936, pages A81–A90. 6 illus. 1 table. 44 equations.

Formulae and Methods of Calculation of the Strength of Plate and Shell Structures in Aeroplane Construction. O. S. Heck and H. Ebner. Simple formulas and methods of calculation for the determination of the stability and strength of structures covered with thin sheet metal (plate and shell structures) in airplane construction. Calculations are given for isotropic, orthotropic, and stiffened rectangular plates, and for circular cylindrical partial and solid shells under various types of load. Journal Royal Aeronautical Society, October 1936, pages 769–788. 12 illus. 63 equations.

Stressed-Skin Structures for Aircraft. D. R. Berlin. Advantages of the stressed-skin structure for aircraft over other types. Adaptability of the structure to machine manufacture for production is considered, and design considerations to give the structure normal life under continued service are discussed. Frequency of overhaul necessary during the life of the airplane is also taken up. S. A. E. Jour. (Trans.), November 1936, pages 444–447, 458. 11 illus.

Aircraft

CZECHOSLOVAKIA

The Benès-Mraz Bibi Light Airplanes. A Frachet. The Czechoslovakian Be-500, 501, and 502 are powered with Walter 25-, 45- and 85-hp. engines and have respective speeds of 155, 190, and 230 km. per hour. The Be-501 won the Coupe des Ailes at the recent "12 Heures d' Angers" contest. Long description. Les Ailes, September 17, 1936, page 3. 3 illus. 2 tables.

FRANCE

Breguet Gyro-Plane. The helicopter is capable of covering distances up to 3730 miles at over 300 m.p.h., according to Louis Breguet. Brief reference. R. A. F. Quarterly, October 1936, page 505.

Dive Tests of Fighter Aircraft. In order to pass the diving tests of the French Air Ministry, fighters must attain speeds in a dive exceeding the maximum horizontal speeds by 30 per cent. Maximum speed in level flight and percentage accredited in the dive are given for the Dewoitine D. 373 and D. 503, Nieuport 161 and Morane-Saulnier 405, the last attaining 298 m.p.h. and 153 per cent in dive tests. Brief reference. R. A. F. Quarterly, October 1936, page 506.

Fighter-Leader Aircraft. The Potez-63 is designed for use as a Fighter-Leader aircraft and is equipped with two Hispano-Suiza 14-HB, 670-h.p. engines. Brief reference. R. A. F. Quarterly, October 1936, page 506.

GERMANY

Deutschland über dem Nord Atlantik. R. Jahn. The Dornier Do-18 which made a survey flight to New York, the Schwabenland from which the flying boat was launched, and the Junkers Jumo 5 Diesel engines powering the Do-18 are described in detail. Aviation, November 1936, pages 15–17, 49. 10 illus.

Dornier Do-22. New German three-seater light bomber, torpedo bomber, or long-distance reconnaissance seaplane has a maximum speed of 198 m.p.h. and a landing speed of 51 m.p.h. when equipped with an Hispano-Suiza 12-cylinder 860-h.p. engine. Various engines ranging from 700 to 900 h.p. may be used. Few details. Aviation, November 1936, page 41. 1 illus.

Replacing the Wal. The Dornier Do-18 flying boat is fitted with a pair of 550-hp. Junkers Jumo 205C Diesel engines providing a range of 2670 miles at a cruising speed of 130 m.p.h., or of 2900 miles at 112 m.p.h. Fuel consumption at the latter speed is 2.05 lb. per mile. Description with special reference to the hull which has a turtle deck and a bottom of unorthodox design. Flight, October 22, 1936, page 421, 1 illus.

The Continual Progress of Diesel Engines. The Junkers Ju 52/3m, G-38 and Ju-86, and the Dornier Do-18 and Do-20 airplanes and seaplanes powered with Junkers Jumo Diesel engines. A few details of each airplane. Les Ailes, September 24, 1936, page 3.

GREAT BRITAIN

Bristol Fashion. The Bristol Blenheim medium bomber which is in quantity production for the Royal Air Force is powered with Bristol Mercury VIII engines giving 840 hp. at 14,000 ft. The absence of a forward gunner and the exceptionally fine outlook are referred to. Only a few details with illustrations. Flight, October 15, 1936, pages 378–379. 6 illus.

Single-Seater High-Altitude Monoplane. Requirements of the British Air Ministry for a high-altitude airplane with details of the record breaking flight and the Bristol 138 airplane and engine with which it was made. Engineering, October 9, 1936, pages 404–406. 3 illus. Aeroplane, October 7, 1936, pages 451–453. 6 illus. Bristols are building a new altitude airplane similar to the 138 record breaker but with a liquid-cooled Rolls Royce engine. Brief reference. Flight, October 15, 1936, page 383.

Air and Water. The new Fairey Hendon twin-engined heavy bombers delivered to the R.A.F. are driven by Rolls Royce Kestrel engines, have a loaded weight of 19,200 lb., carry a crew of four and can be converted into troop carriers. Brief reference. Engineer, October 30, 1936, page 461.

Bread, Bombs or Bayonets. Bristol 130 airplane is planned not only for the transport of armed troops, supplies, spare engines, or gasoline, but also as a long-range bomber of great striking power. With its twin Pegasus 900-hp. engines it is said to have quite astounding performance. Brief. Flight, October 22, 1936, page 414b. 2 illus.

The British Burnelli. The first airplane produced by the Scottish Aircraft and Engineering Company will be powered with a pair of fully supercharged Rolls-Royce Kestrel XVI engines. Stressed-skin construction and a few other details. Flight, October 22, 1936, page 422.

Our Empire Flying Boats. C. G. Grey. A general description and articles entitled "The Beginning of the Empire Flying Boats," H. O. Short; "Some Problems of Big Boat Design," A. Gouge; "How Big Boats Are Built," A. E. Bibby; "Technique of Flying the Empire Boats," J. L. Parker, and "Outside and Inside the Empire Boat," T. James. Structural-detail and sectional drawings, and numerous interior and exterior views of the Short Empire flying boats are included. Aeroplane, October 28, 1936, pages 531–542, 523, 542, 525, 527. Passenger accommodations, piloting and navigational equipment, and the four Bristol Pegasus XC 900-hp. engines. Complete description. A second article entitled "Construction of the Empire Boats" gives the structural details illustrated by drawings. Flight, October 29, 1936, pages 430–434, and (Aircraft Engr. Sup.) 24–28. 13 illus. Sectional drawing illustrating the location of equipment. Aviation, November 1936, page 39. 1 illus.

Winning Ways and Means. F. D. Bradbrooke. Percival Vega Gull which alone reached Johannesburg in the race and was flown back to England. Long description. Aeroplane, October 28, 1936, pages 547–548. 3 illus.

Showing How at Yeovil. Westland Army Cooperation high-wing monoplane is said to be incredibly fast. Slots and flaps used are interconnected and entirely automatic. Interesting design and performance features. Aeroplane, October 21, 1936, pages 501–502, 494, 495. 5 illus. Aerodynamic and structural features with special reference to leading-edge slots and trailing-edge flaps. Flight, October 22, 1936, pages 414c, 414d, 415. 6 illus.

ITALY

Breda 79, 79S. Two new Italian four-seater airplanes for private flying having maximum speeds of 130 and 161 m.p.h., respectively. Few details. Aviation, November 1936, page 41. 1 illus.

Technical Notes. The Italian Cant Z506 seaplane with which eight international speed records for a seaplane with load were broken. Description. L'Aerotecnica, August-September 1936, pages 686–688. 2 illus.

JAPAN

Mitsubishi Monoplane. Two single-engine high-wing monoplanes designed by the Japanese Government Railways and equipped with all the necessary instruments for surveying and emergency purposes. One was remodelled from the Army's "92" type reconnoitering plane, is equipped with a 475-hp. Mitsibushi Jaguar air-cooled radial engine, and has a top speed of 130 m.p.h. The other was remodelled from the "95–2" type training plane of the Imperial army and is equipped with a Nakajima-Jupiter air-cooled engine. Brief. Aviation, November 1936, pages 35, 39. 1 illus.

POLAND

The R. W. D.-XI Light Transport. A Frachet. The new Polish monoplane of mixed construction is equipped with two Walter Major-VI 205-hp. engines and carries six passengers and two pilots at a cruising speed of 255 km. per hour. Maximum speed is 300 km. per hour and range 800 km. Long description. Les Ailes, September 24, 1936, page 3. 4 illus. 2 tables.

U. S. A.

Roadable Autogiro. New type of autogiro with engine located back of the cockpit to provide for transmission of power to the rear wheel driving the autogiro on the road. Design discussed. Aviation, November 1936, pages 33–34. 3 illus.

"States" Evidence. "Although a Pegasus in a single-seater fighter would seem strange to us, the Americans are mounting Cyclone G's in quite diminutive pursuit and combat ships. . . . A pair of similar motors power the new hush-hush Curtiss attack machine which one reads, is the world's fastest twin-engined aeroplane. The Blenheim could probably wag its tail at any of the recent American fighters, as, of course, could the Hurricane and Spitfire if they troubled to slow down." Reference to the Air Corps order for Curtiss P-36 airplanes and a photograph of the Boeing 299 heavy bomber calling attention to the "bomb traps and nasal gun position." Flight, October 22, 1936, page 412. 2 illus.

Stearman P T-13. Model 75 primary trainer biplane used by the Army. Characteristics and performance. Aviation, November 1936, page 35. 2 illus.

"Time Flies." Frank Hawks' new airplane. Accessory equipment briefly referred to with drawing and photograph of the airplane. Aviation, November 1936, pages 34–35. 2 illus.

Aircraft Manufacture

An Industry Comes of Age—First Aero Production Meeting. R. D. Miller. An account of the first National Aircraft Production Meeting of the S. A. E. followed by P. M. Heldt's review of papers presented, including: "Aircraft-Engine-installation Vibration Problems," J. M. Tyler; "Tooling a Medium-sized Airplane Factory," R. A. Von Hake; "Selecting Oil for Aircraft," A. L. Beall; "Spot Welding," B. Burns; "Aircraft Inspection for Airworthiness," R. C. Gazley; "Testing Airplanes for Airline Service," M. Gould. Automotive Industries, October 24, 1936, pages 540–546, 557, 558. 14 illus. Titles and authors of papers. S. A. E. Journal, October 1936, pages 18–19.

Manufacturing Phases of Metal-Aircraft Construction. F. W. Hermann. Materials most widely used in metal-aircraft construction and their important physical properties are described. Problems encountered and processes developed to facilitate manufacture are discussed with particular reference to design, tooling, including lofting, fabrication, assembly, inspection, and protective coating. Methods employed at the Douglas Aircraft Company. S. A. E. Journal Transactions October 1936, pages 394–399. 6 illus. 2 tables.

Aircraft Leaders Swarm to Sessions at Smash-Hit National Meet. An account of the events of first S. A. E. National Aircraft Production Meeting with abstracts of the papers and discussions. S. A. E. Journal, November 1936, pages 14–17, 35–40, 42, 44, 46, 48, 50. 20 illus.

Aircraft Brakes

Airplane Brakes. J. G. Thompson. Autofan streamline wheel brakes and the Bendix disk-wheel mechanical and hydraulic brakes. Maintenance methods. Western Flying, November 1936, pages 20–22. 4 illus.

Something New in Brakes. In the new Avery wheel brakes for aircraft, the brake shoes are mounted as vertically disposed rings, rather after the fashion of clutch plates. There are two of these rings and each is mounted friction surface outwards on a slightly dished metal center. Details of this and another quickly detachable type in which a well-base rim is used. Flight, October 15, 1936, page 384. 3 illus.

Aircraft Carriers

Aircraft Carriers with Landing Platform. Lieutenant Barjot. Airplanes taken on board, carrier platform, carrier speed, tendencies in construction, and the French program for carrier construction are referred to. Brief abstract of paper presented before the Association Technique Maritime et Aéronautique. Revue de l'Armée de l'Air, September 1936, pages 1039–1042.

Propellers

Propeller Straightener. Northwest Air Service device for straightening damaged propeller blades and for repitching Curtiss-Reed or similar propellers. Few details. Aviation, November 1936, page 51. 1 illus.

Reinforced Wood Airscrews. Heine laminated-wood propeller made impervious to the effects of temperature and moisture. Synthetic resin is used for cementing the laminations together and another kind of synthetic resin is sprayed over the surface. A steel gauze coated with copper is applied to the outer three-quarters or so of the blades. Description and table of mechanical properties obtained in tests. Flight, Aircraft Engr. Sup., October 29, 1936, page 23. 1 illus.

Rocket Propulsion

Some Practical Aspects of Rocketeering. W. Ley. Heavily loaded airplanes of the near future may be helped off the ground by means of rocket motors according to the author. Basic principles of rocket behavior, liquid oxygen as the more practical form of fuel and types of fuels investigated, rocket motors, rocket efficiency, and advantages of using launching rockets to facilitate the take-off of airplanes. The author was formerly president of the German Rocket Society. Aviation, November 1936, pages 18–20. 3 illus.

Records and Races

The England-Australia Record. Flight of Miss Jean Batten from England to Australia in five days and 21 hours, which broke the solo record. Log of the flight and a few details of the Percival Gull with a Gipsy Six engine. Aeroplane, October 14, 1936, pages 470, 489. 2 illus. Flight, October 22, 1936, page 409. 2 illus.

The Fourth Deutsch Cup Race. R. J. de Marolles. Details of the Coupe Deutsch de la Meurthe, rules, and the Caudron airplanes and Renault engines entered. Aircraft Engineering, October 1936, pages 271–273. 3 illus.

The Johannesburg Exhibition. F. D. Bradbrook. A discussion of the Race results followed by other articles giving details of the Race. Aeroplane, October 7, 1936, pages 435–444. 10 illus.

One Out of Nine. Description of the Johannesburg Race which was won by C. W. A. Scott and G. Guthrie, the only finishers. In an editorial, the Race is termed a complete fiasco. Specifications of the winning Percival Vega Gull and its Gipsy engine are given in a second article. Flight, October 8, 1936, pages 352–355, 349, 360c–360d. 15 illus.

Some 50,000 Ft. Impressions. Squadron Leader Swain. The pilot's impressions of his record flight to 49,967 ft. in a Bristol 138 monoplane. Flight, October 8, 1936, pages 360a–360. 3 illus.

Engine Design and Research

Altitude Limits Diesel Air Use. F. Prescott. The Air Corps at present is interested in the development of Allison and Continental straight inline engines of approximately 1000 hp. each. There is little likelihood that gasoline aircraft engines operating on the Otto cycle will be displaced by Diesels in the near future. Fuel economy possible with the gasoline engine, the G. E. turbine supercharger, advantages of solid fuel injection, and use of high-temperature coolants are also referred to. Brief abstract of paper presented before the Detroit Section, S.A.E. S.A.E. Jour., November 1936, pages 29–30.

Harmonic Torsional Forces for Four- and Two-Cycle Carburetor Engines. G. Suess. Harmonic analysis of the fundamental curves for four-cycle engines, harmonic torsional forces for various theoretical indicator diagrams, influence of deviations of the actual indicator diagrams from the theoretical, influence of the connecting-rod conditions and of the crossed crank mechanism on the harmonic torsional forces of four-cycle engines, and harmonic torsional forces for two-cycle engines. A.T.Z., August 25, 1936, pages 399–411. 19 illus. 4 tables. 46 equations.

The Selection of Cam Contours. W. D. Bensinger. Influence which the selection of the cam contour will have on the material stressing of the controlled parts at equal valve lift. The values used as a basis for valve timing, valve lift and cam base circle correspond to the values used for a proved airplane engine. Formulas are given for harmonic and tangential cams and cams with curved and hollow flank. A. T. Z., August 25, 1936, pages 412–414. 8 illus.

Analysis of Exhaust Gases. M. Victor. The process for the control of combustion in engines, developed by Claude Bonnier in flight experiments, is said to be exact and practical. An improvement of 30 per cent in fuel consumption was obtained in tests on the Air-France airplanes. Long description. Les Ailes, September 24, 1936, pages 5–6. 4 illus. 1 table.

Author's Conclusion to Discussion of "Liquid-Cooled Aero Engines." H. Wood. Replies to K. Campbell in his discussion on increased cooling of the air-cooled engines; to Lieut. F. D. Klein regarding steps being taken to develop methods of knock testing of high knock-rating fuels which will rate such fuels in accordance with their behavior in the full-scale engine under practical conditions of operations; and to W. Worth regarding the shape of radiators used on Rolls-Royce installations. S. A. E. Journal, Transactions, October 1936, pages 401–424.

Engines with Superchargers. Captain Buffard. Mechanical details of superchargers for aircraft engines with reference to the Gnome-Rhône Type K and Hispano Suiza 12 Ybrs engines, and tests of supercharged engines are discussed in the first issue. The second takes up the automatic control of the intake, with reference to the Hispano-Suiza 12 Ybrs design, cooling with reference to that used on the Renault 9 Fas, Pratt Whitney Wasp, and Gnome Rhône Type K engines, variable-pitch propellers with reference to the Hamilton and Ratier, and French fuels. Revue du Ministère de l'Air, August 15 and September 15, 1936, pages 967–987 and 1160–1175. 21 illus.

Thermodynamic Properties of the Working Fluid in Internal Combustion Engines. R. L. Hershey, J. E. Eberhardt and H. C. Hottel. An exact solution by graphical methods is possible and the method is very similar in nature to those used in connection with the Mollier diagram for steam. Two types of charts are presented, one descriptive of the thermodynamic properties of the air-fuel mixture (and residual products of combustion) before combustion, the other descriptive of the properties of the equilibrium mixture after combustion. Full allowance is made for the variation of specific heats with temperature and for the complex dissociation at the high temperatures attained after combustion. The numerical examples illustrating the use of the charts cover the calculation of the performance of various ideal engine cycles including unthrottled, throttled, supercharged, variable-cutoff, compression-ignition and gas turbines. Effects of different operating variables upon performance, calculated by the described technique, are shown graphically. S. A. E. Journal, Transactions, October 1936, pages 409–424. 9 illus. 7 tables.

Volumetric Mensuration. Compressed air is used to measure the contents of the fuel tank in a new system developed by W. Leigh and said to be particularly well adapted to large airplanes and flying boats. The volume of the air space in the tank is measured and deducted from the known tank volume. The subtraction is done automatically and the gage indicates the liquid contents of the tank directly. Brief description of operation with drawing of parts. Aeroplane, October 14, 1936, page 489. 1 illus.

Engine Testing

High-Altitude Flight Test Stand. Liebel. Fiat test chamber for testing air- and water-cooled aircraft engines under high-altitude flight conditions. Air pressure, temperature, humidity, and wind intensity are controlled. Tests may be made on air-cooled engines up to 500 hp. at constant performance up to 5000 m. altitude, and then at decreasing performance up to 10,000 m.; water-cooled engines up to 1000 hp. at constant performance up to 5000 m. and then at decreasing performance up to 10,000 m. altitude; and water-cooled engines up to 500 hp. at constant performance up to 10,000 m. It is said that the observer can remain in the test chamber at speeds up to 160 km. per hour. Long description of installation and operation. A. T. Z., September 25, 1936, pages 457–463. 15 illus.

Sapphire and Other New Combustion-Chamber Window Materials. G. Calingaert, S. D. Heron and R. Stair. Materials available and suitable for the construction of transparent windows employed for observation inside the combustion chamber, including quartz, spinel, sapphire, periclase, and fluorites. Transparency in the infra-red region increases in the order given and mechanical strength varies greatly, being highest for sapphire and lowest for fluorite. Resistance to chemical action of combustion products varies widely. Sapphire is not attacked by any products of combustion, not even by the lead oxide present when leaded fuels are used. S. A. E. Jour. (Transactions), November 1936, pages 447–450. 3 illus. 1 table.

The Single-Cylinder Test Engine. Test engine for testing airplane-engine cylinders under conditions as nearly similar to flight as possible. The engine was developed at the Institute for Research on Automobile and Aircraft Engines at the Stuttgart Technical High School. The cylinders may be tested in the vertical as well as in inverted or horizontal positions. In another test engine described, cylinders up to 130 mm. in diameter with vertical or inverted valves may be tested. A. T. Z., September 25, 1936, pages 453–455. 5 illus.

Engines and Accessories

Compressed Power. The new Renault air-cooled inverted Vee 12-cylinder aircraft racing engine develops 450 hp. and has a capacity of 8 liters. Few details only. Flight, October 15, 1936, page 387. 1 illus.

Eliminating Noise Exhaust. The Burgess Model F. K. reflection type of silencer developed at the Royal Aircraft Establishment is said to give a noise reduction of 23 phons for a back-pressure reading of 0.3 lb. per sq in. It is also claimed that with a properly arranged exhaust system it is possible to obtain more power silenced than with open exhaust ports. Brief reference to tests which the silencer was given. Flight, October 15, 1936, page 400.

Ignition Screening. Two new systems of engine ignition screening introduced by the Marconi Wireless Telegraph Company and the Technical Improvements Company. The former system is applied to the radial engine and used on the Pegasus XC engines, while the second is used on the Napier-Halford Dagger in which the main conduits are of pure aluminum and the short links of flexible aluminum tubing. Installation in the Dagger is illustrated. Flight, October 8, 1936, page 362. 3 illus.

Lightweight Propulsion. Ava two-stroke four-cylinder horizontally-opposed engine developing 25 hp. at 2250 r.p.m. Brief description with construction drawing. Aeroplane, Aeronautical Engineering Supplement, October 7, 1936, pages 454–455. 1 illus.

New Rotary Engine. The engine developed by M. Richard is of unusually small projected area (7.1 in. in diameter). It is a single-cylinder two-stroke engine making use of the Cadenacy effect whereby scavenging is effected by a vacuum created by the exhaust. Two pistons, connected to two crankshafts, move in opposite directions at any given time. With a bore of 2.90 in. and stroke of 2x2.56 in. the engine is said to develop 20 hp. at 4000 r.p.m. Brief abstract from La Technique Moderne, June 15. Automotive Industries, October 17, 1936, page 527.

Allis-Chalmer Develops Spark Ignition Oil Engine. N. Fodor. New fuel-injection spark-ignition engine for tractors. Detailed description. Abstract of paper presented before the A.S.M.E. Automotive Industries, October 17, 1936, pages 524–526, 528. 6 illus.

Government Prize for Heavy-Oil Engine. Clerget, Junkers, C.L.M., Jalbert, Szydlouski-Salmson, and Rescovice-Botali heavy-oil aircraft engines to participate in the competition for the 132,000 francs offered by the French Air Ministry. The award will go to the first heavy-oil aircraft engine constructed in France and powering the airplane which beats the speed record over 6210 miles. Brief reference to present stage of development of these engines and to the airplanes to be equipped with them. R. A. F. Quarterly, October 1936, pages 506–507.

The Series G Cyclone. Details of the new Wright 1000-hp. engine which was "until quite recently on the secret list of the U.S. Army and Navy Air Services." Long complete description. Aircraft Engineering, October 1936, pages 284–287. 6 illus. Illustrations of engine, supercharger parts, crankcase sections, crankshaft, and reduction gear. Flight, October 15, 1936, page 388d. 4 illus.

Technical Notes. The new Lorraine "Sterna" 12-cylinder engine develops 810 hp. at 2575 r.p.m. at 4000 m. and weighs 503 kg. complete with accessories. Brief reference to this engine and to the 18-cylinder 1000/1200-hp. Sirius. Les Ailes, October 1, 1936, page 3.

Fuels and Lubricants

Combustion Qualities of Diesel Fuel. G. D. Boerlage and J. J. Broeze. Fuel influences the mixing process by its viscosity, its volatility, and its ignition quality, and the optimum value of each property varies with the engine type. Combustion in compression-ignition engines is mostly of the destructive type and under certain conditions it may be partially an oxidation process—for example, according to the hydroxylation theory. Influence of fuel characteristics on the mixture, results of engine experiments on light and heavy fuels, and chemical considerations of after-burning and unburned products are discussed and the necessity for a better criterion for volatility of Diesel fuels is emphasized. Industrial & Engineering Chemistry, Industrial Ed., October 1936, pages 1229–1234. 14 illus., 4 tables.

A Critical Study of Alcohol-Gasoline Motor Fuel Published. J. Z. Schneider. Results of comparative tests made in Prague on two small Praga engines with gasoline and alcohol-gasoline mixtures of various compositions to demonstrate the real practical value of both fuels for the motorist. Summary only given. Industrial & Engineering Chemistry, News Ed., October 20, 1936, pages 413–414.

The Precision of Knock Rating. D. B. Brooks. Antiknock qualities of gasoline can be ascertained within relatively small probably octane unit errors, if suitable precautions are observed in the application of the test methods developed by the Cooperative Fuel Research group. Results of 2180 tests on 99 fuels. S.A.E. Journal, October 1936, pages 22–24, 3 tables.

New Rating for Anti-Detonating Quality. A new scale for the anti-detonating quality of fuels for carburetor engines developed by M. Serruys. The method is said to furnish a synthetic index and to compare the effective powers obtained in one and the same engine with the fuel under test and with a reference fuel such as a pure compound or a mixture of pure compounds such as octane and heptane. Brief abstract from Genie Civil, March 21. Automotive Industries, October 17, 1936, page 527.

Aircraft Instruments

Automatic Trigonometry. Hagner position finder consists of the horizon plane, and the declination, latitude and altitude arcs. Comments of Lt.-Commander P. V. H. Weems on its value in computing lines of position after the necessary altitudes have been found by the sextant, and for other uses. Few details. Aeroplane, October 21, 1936, page 517. 1 illus.

Compass-Swinging in the Air. J. Hartoz and M. Boel. Method of checking an aircraft compass while aloft. Details of a method used by two pilots. Aeroplane, October 21, 1936, page 515. 2 illus.

Carbon-Monoxide Indicators for Aircraft. S. H. J. Womack and J. B. Peterson. Modifications made to commercial carbon-monoxide indicators to make them more suitable for use on aircraft. The alarm attachment to indicate the presence of CO in excess of 0.02 per cent, performance characteristics, and methods of field testing are discussed. Development of the Bureau of Aeronautics, Navy Department. Instruments, October 1936, pages 283–285. 7 illus.

The Continuous Electrical-Acoustical Altimeter. An automatic aerial sounder for short waves and improvements to electrical-acoustical sounders, two French patents of Badin and Jacquet, are described. The method proposed is said to be entirely different from the Askenasy acoustical sounder. The duration of each emission varies with the height of the sounding, two successive emissions being automatically separated by a silence of the same duration. Long description. Revue de l'Armée de l'Air, September 1936, pages 1069–1074. 3 illus.

New Equipment. The new Aera type E. 10 magnetic compass for aircraft, the Aera order transmitter mounted on the Amiot and Bloch multiplace fighters, and the Guinard gasoline pump are described. Revue de l'Armée de l'Air, September 1936, pages 1063–1068. 8 illus.

The Variation of the North. J. Delsuc. Explanation of the theory of the phenomenon which affects magnetic compasses. Revue du Ministère de l'Air, September 15, 1936, pages 1129–1138. 5 illus.

Aircraft Radio

Radio on Germany's Latest Floating Island. Radio equipment on the Ostmark floating base for German aircraft in the South Atlantic. Brief. Wireless World, July 31, 1936, page 99. 2 illus.

Wireless at the Helm. The British Queen Bee pilotless airplane recently was launched by wireless, and after a three-hour flight brought down safely on a rather choppy sea. Brief reference with photograph of launching from H.M.S. Neptune. Wireless World, October 23, 1936, page 438. 1 illus.

Meteorology

Advances and Developments in Weather Forecasting. R. H. Weightman. Vertical structure of cyclones and anticyclones, including the Bjerknes cyclone model and air-mass analysis, and kinematical methods including movement of troughs, fronts, highs and lows, change in intensity, fronto-genesis and cyclo-genesis. Journal Franklin Institute, November 1936, pages 527–549. 9 illus.

Checking Up on Hurricanes. Temperature, pressure, and humidity recording instruments sent aloft in sounding balloons. Brief description of instruments and balloon. Scientific American, December 1936, page 333. 3 illus.

Fog Dissipator Developed. Apparatus capable of clearing ground fog over a radius of half a mile and to a minimum ceiling of 500 ft. was tested in San Francisco. The process, which was developed by C. R. Pleasant, creates a dry area which attacks and dissipates the fog. Brief reference. Western Flying, November 1936, page 19.

Getting Ahead of the Weather. M. T. Rogers. Some modern methods for long-range forecasting with reference to the radio meteorograph and an outline of the possibilities for future studies. India Rubber World, November 1, 1936, pages 42–44. 4 illus.

Airport Equipment

Long Span Steel Arches Incorporate Sawtooth Roof. Unique design of the airplane assembly plant of the Douglas Aircraft Company assures adequate light over a 285x296-ft. columnless area. Top chords of the arches, left outside of the building, are boxed in sheet metal housings. Structural details and erection methods. Engineering News Record, October 15, 1936, pages 542–544. 3 illus.

Metals

The Wear of Metals under Sliding Friction. Method of B. Kehl and E. Siebel for studying the combined effect of a number of important factors influencing the practical performance of materials for piston rings and cylinders and other parts. Abstract from Archiv Eissenhuettenwesen, May. Engineer, Metallurgist Sup., October 30, 1936, pages 164–165. 1 illus., 1 table.

Anodising—What It Is. Process followed by Airwork, Ltd., in manufacturing fuel tanks for British airplanes. A few details with a brief reference on the same page to the advantages of Nulac synthetic resin finishes for metal aircraft and an asbestos cement for aircraft buildings. Flight, October 22, 1936, page 425.

Paint

Making Airplanes Weatherproof. W. Hardy. Specifications, methods of preparation of the surfaces, gas and oil resistance, protection of aluminum-alloy surfaces, chromate treated magnesium surfaces, organic coatings, pigmentation, and application of dopes. Abstract from Paint Manufacturer. Paint, Oil & Chemical Review, October 15, 1936, page 44.

Rubber

"DuPrene" Withstands Sunlight. Report by the Material Division comparing the advantages of Duprene fabric for balloons over rubberized balloon cloth in regard to escapage of gas and deterioration. Brief reference. India Rubber World, November 1, 1936, page 56.

Parachutes

Medical Considerations on Parachute Jumping. Medical Commandant Flamme. Captain Harry Armstrong's experiences in parachute jumping are quoted from the Journal of the American Medical Association and recent Russian experiments are reviewed. Physical ordeals sustained by the jumper are discussed with calculations of the velocities in descent, and the force, frequency, and effects of the wind. The physical aptitude necessary for the jumper and medical contra-indications are taken up and various methods of training parachute jumpers are described. Revue de l'Armée de l'Air, September 1936, pages 977–1006. 15 illus.

Photography

Abstracts of Papers for the Rochester Convention, October 12–15, 1936: "The Development of the Art and Science of Photography in the Twentieth Century," C. E. K. Mees. "A Record Word-Spotting Mechanism," R. H. Heacock. "Modern Loud Speaking Telephones and Their Development," C. Flannagan, R. Wolf, and W. C. Jones. "A Review of the Quest for Constant Speed," E. W. Kellogg. "The Schwarzkopf Method of Identifying Criminals," J. Frank, Jr. "Medical Motion Pictures in Color," H. B. Tuttle. "Color Photography," C. E. K. Mees. "Manufacture of Motion Picture Film," E. K. Carver. "Stability of Motion Picture Films as Determined by Accelerated Aging," J. R. Hill and C. G. Weber. "Care of Slide-Films and Motion Picture Films in Libraries." C. G. Weber and J. R. Hill. "Fire Prevention in the Motion Picture Industry," H. Anderson. "The Projection of Lenticular Color Films," J. G. Capstaff, O. E. Miller and L. S. Wilder. "Effect of Lens Aberrations on Image Quality," W. B. Rayton. "Mercury Arcs of Increased Brightness and Efficiency," L. J. Buttolph. "Trick and Process Cinematography," J. A. Norling. "Report of Standards Committee," E. K. Carver. "The Performance Record of an Automatic Recording Densitometer," C. M. Tuttle and M. E. Russell. "A Developing Machine for Sensitometric Work," L. A. Jones, M. E. Russell, H. R. Beacham. "Some Aspects of Reduction Printing," G. Friedl, Jr. "The Influence of Sprocket-Hole Perforations upon the Development of the Adjacent Sound-Track Areas," J. G. Frayne and V. Pagliarulo. "A New Type of Peak Reading Volume Indicator," F. L. Hopper. "A Neon Type Volume Indicator," S. Read, Jr. "A Neon Tube Oscilloscope as a Utility Instrument for the Projection Room," F. H. Richardson and T. D. Hover. "Recent Developments of High-Intensity Arc Spotlamps for Use in Motion Picture Production," E. C. Richardson. "Film-Editing Machine Embodying Optical Intermittent Projection," J. L. Spence. "New Recording Equipment," D. Canady and V. A. Wellman. "An Improved Reel-End Alarm," D. Canady and V. A. Wellman. "Three-Wire D-C. Supply for Projection Arcs," C. C. Dash. "A Demonstration Triode for Visualizing Electronic Phenomena," F. E. Eldredge and H. F. Dart. Brief abstracts. Journal, Society Motion Picture Engineers, October, 1936, pages 480–492.

Armament

Kindness to Gunners. Gun turret developed by Boulton and Paul to protect the gunner from wind and cold and relieve him of muscular effort in aiming the gun. The turret also serves as a station for the bomb aimer. Photographs with explanation of the turret operation and reference to the engine-driven six-cylinder air compressor used. Aeroplane, October 21, 1936, page 496, 4 illus. Longer description of the turret fitted to the Boulton and Paul Overstrand bomber. Flight, October 22, 1936, pages 414a and 425. 4 illus.

Random Notes on a Visit to the United States and Australasia. W. S. Shackleton. The new 37-mm. aircraft cannon of the American Armament Corporation is described in an account of impressions received during visits to aircraft and engine plants in the United States. Douglas, Boeing, Lockheed, Consolidated, and Vultee are said to be making provisions for this cannon in their new designs and the author's firm is planning to manufacture the cannon in Great Britain. The cannon is compared with other United States and foreign aircraft guns and conclusions derived from tests are discussed. Reasons are given why this is considered definitely to offer the most effective defense weapon against attack of aircraft equipped with light and heavy machine guns and machine-gun cannons. Aeroplane, October 21, 1936, pages 509–510. 2 illus.

Various Notes. A torpedo dropped from Italian aircraft is armed with a parachute which automatically detaches itself when the torpedo strikes the water. The torpedoes are dropped from altitudes of 10,000 to 15,000 ft. Although experiments have not been as successful as expected, a number of aviation squadrons have been equipped with these torpedoes. Brief reference only. U.S. Naval Institute Proceedings, November 1936, page 1647.

Air Forces

Foreign War Orders for U. S. Prospects of a rush demand for American military airplanes this winter, and airplane production abroad. The Soviet Union is credited with a production of 5000 airplanes a year, and Germany with 4000. The British are said to have been unexpectedly slow in getting into the rearmament business, particularly in the air, and a British order for 700 complete American airplanes is rumored. Evidence that Soviet-German bitterness is becoming acute, and a new French air-defense program costing more than $230,000,000 are referred to. Business Week, October 31, 1936, pages 18–19. 5 illus.

FRANCE

Events Abroad. Two of a series of "Sacrifice Squads" have been added to the French Air Force. They are composed of parachutists whose task in wartime will be to drop behind the enemy lines to organize the bombing of vital objects such as munition factories and important strategic points. Three more squads are in the process of formation. Brief reference. R. A. F. Quarterly, October 1936, page 505.

Aeronautical Training for the Technical Corps. L. Hirschauer. Organization, airports, material, personnel and future of the French Technical Corps. Revue du Ministère de L'Air, September 15, 1936, pages 1095–1123. 6 illus., 8 tables.

GREAT BRITAIN

Calshot Re-Visited. C. M. McAlery. History and present organization of the R.A.F. school of naval cooperation with a brief reference to the Saro London flying boats used in training. Aeroplane, October 7, 1936, pages 447–450, 12 illus.

The British Air Force of Asia and Egypt. British air force units assigned to the Irak, Egypt, Syria, Transjordan, Afghanistan, and India. From Corricre della Flotta Aerea, No. 3. Rivista Aeronautica, September 1936, pages 339–343. 6 tables.

Home Commands. Flying tests which the pilot must pass under the new Royal Air Force training scheme. R. A. F. Quarterly, October 1936, pages 503–504.

ITALY

Italo-Ethiopian Conflict. Role played by the Italian Air Force in the campaign in East Africa and statistics of the activities. R. A. F. Quarterly, October 1936, pages 509–510.

LITHUANIA

Foreign Service News. Organization of military aviation in Lithuania and courses at the military aviation school. Brief. Aeroplane, October 21, 1936, page 506.

PORTUGAL

Air Exercises Over Lisbon. Account of mock air raid performed on May 27 by 21 military aircraft and four naval aircraft. Brief. R. A. F. Quarterly, October 1936, pages 512–513.

SPAIN

Foreign Service News. Bombing of Madrid and Cadiz in the Spanish revolution. Brief reference. Aeroplane, October 21, 1936, page 506.

SWEDEN

Reorganization of the Swedish Air Force. Reorganization and expenditure approved. Brief reference. R. A. F. Quarterly, October 1936, pages 512–513.

U. S. A.

Naval Aviation. Rear Admiral A. B. Cook. Development and needs of naval aviation in regard to material, heavier-than-air operations, and personnel. U. S. Naval Institute Proceedings, October, 1936, pages 1455–1458.

Increase in the Effective Force of the Air Corps. Photographs of the recent Martin bimotored and Boeing 299 bombers. Revue de l'Armée de l'Air, September 1936, pages 1042–1044. 3 illus.

Seversky BT-8. Photographs of the new Seversky biplane training plane for the Air Corps. Under "Technical Notes" reference is made to the Air Corps order for Curtiss Y-A-18 airplanes powered by two Wright Cyclone GR-1820 engines, and to the Navy order for 50 Consolidated V.P. 13 airplanes. Les Ailes, September 24, 1936, pages 1 and 5. 3 illus.

U. S. S. R.

The Huge Russian Aeronautic Plants. A. Langeron. Comments on a visit to the Russian plants producing aircraft and engines. Les Ailes, September 17, 1936, page 7.

Martin Boat for Russia. A 44-passenger flying boat is being built for Russia by the Glenn Martin Company. Brief reference. Flight October 22, 1936, page 422.

Air Warfare

Air Strategy. Lt.-General N. N. Golovine. Aircraft for cooperation with the Army and Navy as distinct from, and compared with, those types recommended for the armament of an Independent Air Force. Strategic Army reconnaissance to be used when the enemy is at a considerable distance and specifications and equipment for Army strategic reconnaissance aircraft, tactical air reconnaissance and aircraft equipment, advantages of the autogiro in liaison and observation, the characteristics and duties of the Army fighter, criticisms of ground attack, and the infantry-communication airplane, are discussed with the comment that inclusion of heavy transport aircraft in the Army Air Service organization is unnecessary. For the Fleet Air Arm deck-flying aircraft including torpedo-spotter-reconnaissance and fighter aircraft, aircraft for catapult launching, and flying boats and seaplanes are also taken up. In the concluding chapter, dealing with the divisions and organization of the air defense system of the Empire, the authors discuss in detail the Army Air Service and Fleet Air Arm, permanent Metropolitan defense. Air control in the Middle East, India and Malacca Straits, mobile defense force for the defense of the United Kingdom and Imperial routes, and the achievement and maintenance of superiority in the air over the Lower Rhine and Mediterranean. Under war conditions the material consumption is estimated at 17,250 aircraft per year. Concluded. R. A. F. Quarterly, October 1936, pages 405–434. 1 illus., 9 tables.

The Airplane in International Law. Lieutenant E. R. McLean, Jr. Historical review of the progress of International Law in regard to aircraft and aerial warfare. U. S. Naval Institute Proceedings, November 1936, pages 1533–1543.

Balance of Power in the Mediterranean and the Air Force. Ten. Col. V. Lioy. Relations entering into foreign and military politics, the problem of the balance of power in the Mediterranean with respect to the military power of Italy, France, and Great Britain, and the profound changes brought about by air forces are discussed. Present factors in the balance of power are examined in regard to the new international situation determined with the creation of the Italian Empire. Rivista Aeronautica, September 1936, pages 267–282.

Bomber Formation. The new scheme of bomber formation is said to permit freedom of maneuver, to insure mutual supporting fire, to offer greater field of fire, to reduce risk of collision, to facilitate control by the leader, to enable an assailant to employ only part of his formation which, meanwhile, is exposed to the fire of the whole of the bomber formation, and to have other advantages. Résumé of a previous article by Flight Lt. A. H. H. MacDonald and a scheme put forward by Colonel P. Piacentini in L'Ala d'Italia, April 1935. R. A. F. Quarterly, October 1936, pages 441–446. 5 illus.

The Mobile Squadron on Imperial Routes. Flight Lt. G. P. Charles. Imperial reinforcing by air and the need for a very different organization and type of equipment to that in use at present. Personnel required for reinforcement units, aircraft and equipment necessary, and the provision and equipment for Imperial air bases. R. A. F. Quarterly, October 1936, pages 435–440.

"New Theory of Firing between Airplanes." Further criticisms of the new theory of fire between airplanes explained by Captain Colangeli in the April issue and discussed in subsequent issues. Rivista Aeronautica, September 1936, pages 301–306. 1 illus.

The Aerial Mission of War. Lt. Col. A. Struc. Objective, execution, and knowledge required of the crew on an aerial mission in time of war. Revue du Ministère de l'Air, September 15, 1936, pages 1139–1159.

Bombing at Low Altitudes. C. Rougeron. The method of bombing at low altitudes has been praised by Colonel Mecozzi and is in current practice in Italian aviation. The author discusses the conditions which the method satisfies in regard to safety and examines it from a ballistic point of view. He compares it with methods of dive bombing and horizontal bombing. Long abstract from the book entitled "Bombardment Aviation." Revue de l'Armée de l'Air, September 1936, pages 1007–1024. 1 illus., 5 tables. Review of book. Revue du Ministère de l'Air, August 15, 1936, pages 1067–1071.

Ground Defense Against Hostile Aircraft. A. L. Rawlings. Possibilities of anti-aircraft fire and the operation of the Sperry predicting machine are discussed in detail. The range finder is considered the weakest link in the process. Sperry and Goerz sound locators are also described. Reference is made to load, speed and range of the Douglas and Boeing bombers. Paper presented before the British Association. Engineering, October 16, 1936, pages 429–431.

Will High Speeds Stop the Pursuit? A. Odier. Increased airplane speeds are said to give to the fugitive such a ballistic advantage that pursuit will be impossible. This general discussion of the problem is followed by R. Garnier's article entitled "Problem of the Ballistic Superiority of Fire in a Retreat," which calculates the special case of an armed airplane retreating at 450 km. per hour and followed by a pursuit plane make 500 km. per hour. The two airplanes are equipped with 20-mm. "canons" which fire 400 rounds per minute, the projectiles having a maximum range of 5500 m. and an initial speed of 830 m. per second. Revue de l'Armée de l'Air, September 1936, pages 963–976. 3 illus.

Organizing Collective Security. Wing Commander R. E. G. Fullijames. Problems in organizing collective security in Europe on a sound military basis, with reference to a collective air force. R. A. F. Quarterly, October 1936, pages 474–478.

The Problem of the Pursuit of Today. Ten. Col. A. Serra. Present problems of pursuit aviation are analyzed and the requirements of pursuit airplanes in regard to armament, speed, range, strength, visibility, and accessories are discussed in detail. A table gives the useful load, dead load, and their ratio for the Curtiss B.F.-2CI, Boeing 281, and a number of Polish, French, German, British, and Italian airplanes. Rivista Aeronautica, September 1936, pages 283–300.

Miscellaneous

Buyer's Log Book. Curtiss Pneumatic hydraulic hoist, Delco hydraulic retractable landing lights for aircraft, Hagner position finder, and Air Transport aircraft skiis. Few details. Aviation, November 1936, page 43. 5 illus.

Change of Boiling Point of Liquid Oxygen at High Altitudes. J. Piccard. Imminent danger to aviators in descending from high-altitude flights when using a breathihg mask supplied with oxygen from a bottle of liquid gas. On descent the boiling and gas production stop entirely and, in addition, the cold liquid begins to condense nitrogen and oxygen at its surface. Air is even sucked back from the gas mask into the bottle. Experience in a stratospheric balloon flight. Journal Aeronautical Sciences, September 1936, page 406.

Exit the Villain—Ice. F. L. Hattcom. Deicing equipment installed on T.W.A. airplanes. Western Flying, November 1936, pages 16–17. 3 illus.

FIFTH ANNUAL MEETING AND DINNER

of the

INSTITUTE of the AERONAUTICAL SCIENCES

to be held

WEDNESDAY, THURSDAY AND FRIDAY, JANUARY 27-28-29, 1937

PUPIN PHYSICS LABORATORIES, COLUMBIA UNIVERSITY

BROADWAY at 120th STREET, NEW YORK CITY

THREE DAYS TECHNICAL SESSIONS

ANNUAL MEETING OF MEMBERS

ANNUAL DINNER

SPECIAL SHOWING OF

MOVING PICTURES

of

LABORATORIES AND WIND TUNNELS OF EUROPE

McMILLEN THEATRE, COLUMBIA UNIVERSITY

WEDNESDAY, JANUARY 27, 1937